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LIST OF ACRONYMS

EPA:	United States Environmental Protection Agency
GIS:	Geographical Information System
GPS:	Global Positioning System
DEQ:	Montana Department of Environmental Quality
DPHHS:	Montana Department of Health and Human Services
DRASTIC:	See section 4.13
District:	Missoula Valley Water Quality District
MCCHD:	Missoula City-County Health Department
MWTPSA:	Missoula Waste Water Treatment Plant Service Area
OCD:	Missoula County Office of Community Development
PLSS:	Public Land Survey System
QA/QC:	Quality Assurance and Quality Control
RSID:	Rural Special Improvement District
SEWPER:	Septic System Permit Database, Missoula County
USDA:	United States Department of Agriculture
USGS:	United States Geological Survey
VOC:	Volatile Organic Compound
WWTF:	Missoula Waste Water Treatment Facilities

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1.0 INTRODUCTION

This report is organized into seven sections. Section one describes the purpose and limitations of the study and provides background information. Section two provides information on historical outbreaks of groundwater borne disease, summaries of local studies related to septic systems and groundwater, and summaries of other regional studies related to septic systems and groundwater. The most common types of septic systems, alternative septic systems, characteristics of residential waste water, and the fate and transport of septic system contaminants are summarized in section three. The methods used to complete this study are described in section four. The results of the study are presented in sections five, six and seven. Section five describes the results for water quality and public health factors evaluated for each unsewered area. Section six provides a relative ranking of unsewered areas and specific quarter sections, with respect to current water quality and potential health risks. Section seven provides a summary of the results by area. Several maps are included as attachments, and appendices and references cited are provided for additional information

1.1 PURPOSE

The purpose of this study was to conduct groundwater related research in high density, unsewered areas to assist in policy decisions regarding installation of public sewer. The following specific research objectives were established for the study:

1) review local, regional and national literature on water quality and public health impacts of septic systems,

2) collect water quality data, hydrogeologic data and data on septic systems and water supplies in high density, unsewered areas within the Missoula urban area,

3) evaluate and rank current environmental and public health impacts in each area,

4) assess vulnerability to contamination in each area,

5) Rank the areas based on the relative need for public sewer, based on public health and environmental factors.

The study is intended to complement the Missoula County Carrying Capacity Study and the City of Missoula's Wastewater Facilities Plan Service Area Update. The Carrying Capacity Study, funded by the Board of County Commissioners, is evaluating future development capacity within the County, using conventional septic systems. The Wastewater Facilities Plan Service Area Update is evaluating the future needs of the Missoula Wastewater Treatment Facility.

This study evaluated existing high density developed areas not served by public sewer. It is a composite analysis of the risks to groundwater, surface water and public health, posed by high density unsewered areas within the Missoula Valley Water Quality District. The study documents historical water quality, current water quality, aquifer vulnerability, septic system densities, types of septic systems, septic system failure rates since 1967, densities of commercial properties and cumulative impacts/loading of sewage to groundwater in each high density, unsewered areas.

1.2 LIMITATIONS

This study analyzes, and ultimately ranks, unsewered areas according to resource protection and public health factors. It does not employ epidemiological methods and does not document or quantify specific public health effects. The study was prepared for technical use by policy-makers and the public. It is not a policy statement and does not address aspects of sewering such as proximity to existing sewer mains, engineering requirements or costs for connection of high density areas to public sewer. These factors may alter the priority and feasibility of connection to public sewer, and the ranking provided by this study, which considered only environmental and public health factors.

This study considered impacts of current development within high density, unsewered areas. It did not evaluate potential impacts of future development. A rapidly growing area may be a high priority for extension of public sewer, despite a low ranking in this study, because it makes more sense to install sewer during development than to retrofit after roads and utilities have been installed.

1.3 BACKGROUND

Septic systems have frequently been identified as sources of both localized and regional groundwater contamination (Canter and Knox, 1985). Approximately 800 billion gallons of sewage is discharged to groundwater annually in the United States, via septic systems (Yates, 1985). Nationally, septic systems are the most frequently reported source of groundwater contamination, and they represent the single largest source of groundwater contamination by volume (Bauman and Schafer, 1985).

Septic systems are widely used over the Missoula Valley Aquifer, which is Missoula's sole source of drinking water. Groundwater pumped from the aquifer is distributed without treatment, except for chlorination in some cases. The aquifer is susceptible to contamination from septic systems due to the coarse nature of the aquifer materials and soils in many areas, the shallow depth of the water table and the lack of a protective layer between the surface and the water table. Septic systems can cause both chemical and biological contamination of groundwater.

Based on information obtained from Missoula County Information Services, as of January, 1995, there were a total of 30,428 residential and commercial units within the boundaries of the Water Quality District. A unit is defined as a commercial property, a single family residential property, an apartment in a multifamily development or a mobile home. Of the total units, 18,689 (61.4%) are connected to a public sewer system and 11,739 (38.6%) are connected to septic systems. Many of the units served by septic systems are included within high density urban areas within the Water Quality District. These high density unsewered areas were the focus of this project due to concerns about adverse impacts to water quality and public health.

The older Linda Vista subdivisions, located southwest of Missoula, are an example of the groundwater impacts that have occurred from use of septic systems in high density developments. At least 14 private water wells in the Linda Vista area were found to be contaminated with nitrate-nitrogen (nitrate-N) at levels that exceeded the drinking water standard of 10 milligrams per liter (mg/l) (MCCHD, 1992). The Mountain View public water supply well in the Rattlesnake Valley was abandoned in 1991 by Mountain Water Company due to persistent contamination with both coliform and fecal coliform bacteria. The source of the bacterial contamination was never determined, but septic systems are among the possible sources. In general, prior data were too limited to allow comparison and assessment of water quality impacts and potential health risks from various high density developments within the Missoula urban area.

As growth in the Missoula Valley continues, new homes are being built which are not connected to public sewer. These homes may contribute to water quality degradation while efforts to connect existing homes within the urban area continue. The newly adopted Missoula City-County Health Code, which became effective on August 15, 1994, includes measures to address new development. The Health Code designates much of the Missoula urban area as a special management area, called the Missoula Wastewater Treatment Plant Service Area (MWTPSA).

The purpose of the MWTPSA is to notify landowners that permission to discharge sewage to the subsurface within the area is temporary. Landowners who obtain septic system permits after the effective date of the Health Code must connect to public sewer within 180 days, once it becomes available. The Health Code also requires community septic systems for many new divisions of land within the MWTPSA. This will simplify later connection of the developments to public sewer, and reduce the individual cost for connection. These requirements are currently under review, and may change.

The problem remaining to be addressed is how the City and County of Missoula should handle existing high density unsewered areas. Some of these areas are developed at higher densities than the current Missoula City-County Health

Code would allow. The Health Code allows for development densities of one septic system/acre with private wells or two septic systems/acre with public water. Most septic systems in existing high density areas are also not built to current design standards. Many of the homes use seepage pits or cesspools. The main concerns with the existing high density unsewered areas in Missoula are groundwater and surface water pollution, and potential public health risks associated with chemical and biological groundwater pollution.

2.0 LITERATURE REVIEW

A significant amount of literature is available on septic system operation and groundwater impacts from chemical contaminants discharged by septic systems. Less information is available on the groundwater impacts from biological contaminants originating from septic systems. There is limited information available on groundwater borne disease outbreaks and the transport of viruses in groundwater. The following subsections summarize some important local and regional information related to impacts to groundwater from septic systems.

2.1 HISTORICAL OUTBREAKS OF GROUNDWATER BORNE DISEASE

Montana Cases;
Water borne disease outbreaks have occurred in Missoula. One of the earliest documented outbreaks occurred in the Rattlesnake Valley in 1888, when an epidemic of typhoid fever occurred (Water Quality Advisory Group, 1987). The cause of the outbreak is unknown, but both surface water and groundwater were being used.

Between August 4 and September 9, 1995 approximately 400 people contracted gastroenteritis at the Lion's Campground, located on Little Bitterroot Lake in Flathead County (Damrow, 1995). The water supply well at the campground was identified as the most likely source of the illness. A gastroenteric virus is the suspected cause of the illnesses (Damrow, per. com., 1995). A nearby septic system may have contaminated the well. An investigation of the outbreak is being conducted.

An outbreak of gastroenteritis also occurred in Big Sky in 1975 (Cottingham, 1995) and 1995 (Steve Shope, per. com., 1995). Groundwater was implicated as the source in both cases, but an epidemiological investigation was never completed.

National Cases;
Bacterial and viral groundwater borne disease outbreaks are not uncommon. Acute gastroenteritis of unknown origin, hepatitis A, shigellosis and viral gastroenteritis are the most frequent illnesses associated with transmission of pathogens in groundwater (Craun, 1985). Between 1946 and 1980 (34 years) there were 672 reported outbreaks of water borne disease affecting 150,475 people in the United States (Salvato, 1992). Contaminated groundwater was

responsible for 35% (237) of these outbreaks. Many of these outbreaks are recent. Between 1971 and 1978 a total of 224 reported outbreaks of water borne disease affected over 48,000 people in the United States (Craun, 1981). Approximately 90 of these outbreaks were groundwater borne outbreaks believed to be caused by overflow or seepage of sewage from septic tanks and cesspools (Gerba, 1994). Overflow or seepage of sewage, primarily from septic tanks and cesspools, was responsible for 38% of reported outbreaks and 58% of reported cases of illness associated with untreated well water between 1971 and 1980 (Yates and Yates, 1989).

A groundwater borne outbreak of typhoid fever in Yakima County, Washington occurred in May, 1972 (McGinnis and DeWalle, 1982).
This outbreak was caused by transmission of Salmonella typhi from a septic system being used by a carrier, to a shallow well located 210 feet away. This outbreak suggests that the standard 100 foot separation between wells and septic systems may not always be adequate.

In June, 1994, five cases of Shigellosis (dysentery) in Southeastern Idaho were traced back to an overflowing seepage pit that allowed sewage to enter a nearby abandoned well bore, causing groundwater contamination and contamination of two nearby water supply wells (Van Every and Dawson, 1995). The drinking water wells were located 35 to 40 feet from the abandoned well. The wells tested positive for coliform, fecal coliform bacteria and ultimately Escherichia coli.

Shigella sonnei was implicated in an outbreak of gastroenteritis, when 1200 people in a community of 6,500 became ill (Yates, 1985). An epidemiological study indicated the water supply was the source, and further investigation linked contamination of the well to a septic system 150 feet away. Again, this outbreak suggests that the standard 100 foot separation may not always be adequate.

A study completed by the Public Health Service of a septic system at Fort Caswell, North Carolina documented travel of coliform bacteria 232 feet in sandy soil (Salvato, 1992).

Although the techniques for isolation of viruses from groundwater are difficult and relatively new, there are numerous cases where groundwater borne disease outbreaks have been verified to be caused by viruses. Echovirus was isolated from a 40 foot deep well in Florida, after workers in a labor camp began experiencing gastroenteritis. The well was located in the middle of an area bordered by septic systems (Keswick and Gerba, 1980). Numerous other cases of viral contamination of groundwater have been reported. Table 1 shows examples of documented outbreaks of Norwalk-like virus related to groundwater supplies.

TABLE 1
Outbreaks of gastroenteritis attributed to groundwater borne Norwalk-like Virus

LOCATION	YEAR	SOURCE	# OF CASES
Colorado	1976	well	418
Pennsylvania	1978	well	350
Pennsylvania	1978	well	120
Washington	1978	well	467
California	1979	groundwater	30
N. Carolina	1979	well	146
Pennsylvania	1979	well	151
Maryland	1980	well	139

Source: Gerba (1984)

General;
It is probable that limited groundwater borne disease outbreaks caused by septic systems occur more often, but are not recognized and reported (Yates, 1985). Some studies suggest that the actual number of water borne disease outbreaks in the United States is three to ten times higher than reported outbreaks (Craun et. al, 1994). There are several reasons for the lack of recognition and reporting. First, some outbreaks are self limiting, so before an affected individual seeks treatment the symptoms may fade. Second, since there is no monitoring of private drinking water wells, a small group of private wells could become contaminated by pathogenic organisms from an up gradient septic system and never be reported. The individuals in the affected homes may all seek independent treatment and the doctors would have no reason to suspect the groundwater supply, versus other potential sources, unless the same doctor saw numerous patients with the same illness from the same area and recognized a pattern. Third, there is a lack of sanitary survey information on private wells. Fourth, epidemiological investigations of groundwater borne disease outbreaks are often limited, and are not started until several weeks after the outbreak starts. Finally, the standard coliform bacteria test used to determine if groundwater supplies are sanitary doesn't test for pathogenic bacteria or viruses.

This is an important consideration when reviewing coliform bacteria tests for water supplies. A well that tests negative for coliform bacteria may still be contaminated with enteric viruses or other pathogenic bacteria (Salvato, 1992). In the case discussed earlier, where workers in a labor camp in Florida contracted gastroenteritis, echovirus was isolated from the water supply. Residual chlorine was present in the water supply and the water tested negative for bacterial contamination (Keswick and Gerba, 1980).

2.2 LOCAL STUDIES RELATED TO SEPTIC SYSTEMS AND GROUNDWATER

Numerous local studies have been completed that indicate groundwater in the Missoula Valley has been impacted by septic systems. Several studies also indicate that the spread of pathogenic organisms from septic systems to nearby down-gradient drinking water wells could occur given the local aquifer properties.

It is important to note that throughout this report nitrate concentrations are presented as nitrate-nitrogen (nitrate-N) concentrations. The drinking water standard for nitrate-N is 10 milligrams per liter (mg/l). Because only the nitrogen fraction of the nitrate molecule is reported (NO_3-N), the actual concentration of nitrate in a water sample that is reported as 10 mg/l nitrate-N is 44.3 mg/l nitrate.

Chemical analysis of 21 wells in the Missoula Basin was completed by McMurtrey et al. (1965), as part of a study of the geology and groundwater resources of the Missoula Basin. The analysis included nitrate, and is the earliest known groundwater nitrate data in the Missoula Valley. Ten of the wells tested are within the boundaries of the Water Quality District. Two of the wells sampled were in the West Reserve Street area, and the nitrate values were 0.40 and 0.24 mg/l nitrate-N. The highest nitrate result was from a well near the intersection of 39th Street and Russell Street. This well had a nitrate-N concentration of 1.89 mg/l. Two wells were in the Mullan Road area, and had nitrate-N concentrations of 0.16 and 0.20 mg/l. The exact well locations and well depths are unknown, but the nitrate-N levels in the Mullan Road and West Reserve Street areas are lower than the levels documented during this study.

The Chemical Section of the Missoula Valley Water Study was the first major work to document nitrate levels in groundwater and surface water in the Missoula urban area (Juday and Keller, 1978). This section of the study was part of a larger cooperative study of water problems in the Missoula Valley. The study was completed for the Board of County Commissioners. It included chemical analysis of several hundred water samples from private drinking water wells, including wells within high density unsewered areas. Juday and Keller established a background nitrate level of 0.1 milligrams per liter (mg/l) for pristine waters and compared their results to this level. One of their most significant findings was very high nitrate levels in the Linda Vista area. They also concluded that there was evidence of contamination from septic systems within the Missoula Valley but the levels of contamination relative to the drinking water standard of 10 mg/l were low. The study also documented increasing downstream levels of nitrate-N in both groundwater and surface water in the Rattlesnake Valley and Rattlesnake Creek. Table 2 shows the water quality data for four sampling sites along Rattlesnake Creek from the

Trailhead bridge to the Front Street bridge. Several domestic wells sampled by Juday and Keller were re-sampled by the District as part of this study.

TABLE 2
Water quality data for Rattlesnake Creek between the Trailhead Bridge and the Front Street Bridge

SITE	Bicarb	SO_4	Cl	NO_3	Na	K
Trailhead Bridge	22.70*	1	0.4	0.022	1.4	0.4
Lolo St Bridge	38.10	1.5	0.4	0.180	1.8	0.5
Vine St. Bridge	56.70	4.2	1.3	0.550	2.5	0.7
Front St. Bridge	54.80	3.2	1.3	0.490	2.5	0.7

*Units are all mg/l, Source: Juday and Keller (1978)

Water quality sampling was conducted as part of a study of four unsewered areas in Missoula by Newman (1980). Like the study completed by Juday and Keller (1978), this report was prepared and included within a larger report titled Recommendations To Local Government For the Protection Of Water Quality: Mineral, Missoula, and Ravalli Counties, Montana. The report was prepared under the auspices of the Five Valleys District Council, and was funded through a contract with the Montana Department of Health and Environmental Sciences-Water Quality Bureau. Newman conducted the research for the unsewered areas section of the project. An advisory board of the Five Valleys Council selected the four areas based on the lack of municipal water and municipal sewer. The four unsewered areas studied were the Rattlesnake Valley, Grant Creek, Big Flat and Orchard Homes/Target Range. Newman completed chemical analysis on 110 wells in the Rattlesnake, 55 wells in Grant Creek, 50 wells in Big Flat and 62 wells in the Orchard Homes/Target Range area.

The study found that nitrate levels were elevated in most wells in the Rattlesnake Valley. Possible sources of contamination were noted, including septic systems. The relatively low productivity of the aquifer was considered a factor contributing to the elevated nitrate levels. Wells in the Grant Creek Valley had lower nitrate levels and the report concluded that the lower levels were due to deeper wells, larger lots, newer homes and a more productive aquifer system (as compared to the Rattlesnake Valley). The study also documented elevated nitrates in the Orchard Homes/Target Range area. Four wells in this area had significantly elevated nitrate levels. These elevated levels were attributed to direct impacts from nearby septic systems. A study completed by Ver Hey (1987) was the first local study that documented the fate and transport of septic system contaminants. Ver Hey documented the level of treatment of sewage from two residential septic systems in the Orchard Homes area. The homes were using drainfields built to local health standards existing at the time of construction. The two septic systems were instrumented with shallow groundwater monitoring wells, soil water samplers (suction lysimeters) and sampling ports for direct access to the septic tanks. Water meters were installed to determine the amount of discharge to the septic systems. Ver Hey determined that the daily loading to each system was approximately 200 gallons. Groundwater at the site varied in depth from 8 feet to 15 feet.

The study documented significant degradation of water quality below and immediately down gradient from the drainfields. Nitrate-N concentrations in groundwater within the septic system plumes ranged from 6.87 to 19.47 mg/l. Fecal coliform bacteria were found to pass readily through the coarse soils beneath the septic systems. Fecal coliform analysis of groundwater directly below the septic systems showed contamination above the maximum detection limit for the analysis. Fecal coliform bacterial contamination at 8 colonies/100 milliliters (ml) was also detected 50 feet down gradient from the septic system. Ver Hey concluded that the septic systems were directly impacting groundwater due to the coarse sediments in the area, and that dilution of the sewage was the only significant form of treatment. She also documented that only a small portion of the drainfields were working, allowing effluent to infiltrate over a much smaller area than intended.

A study of the hydrogeology of the eastern portion of the Missoula Valley was completed by Woessner (1988). One of the goals of the study was to build on existing water quality data to determine the human-caused effects on the aquifer and assess the potential for future problems. The study included water quality sampling in high density unsewered areas. During the study, 26 monitoring wells and six Mountain Water Company wells were sampled quarterly for five quarters. This sampling was completed between February 1986 and May, 1987. During the last quarter of sampling, an additional 66 domestic wells located west of Reserve Street were also sampled.

The results of the water quality sampling showed a general increase in total dissolved solids (TDS) down gradient in the aquifer. Chloride and nitrate concentrations were found to generally increase down gradient in the aquifer. None of the nitrate-N levels documented exceeded 2.0 mg/l. Bacterial contamination of groundwater west of Reserve Street was also documented. Out of a total of 98 bacterial samples that were collected during Spring, 1987, 18 (18%) tested positive for coliform bacteria. Of the 18 positive samples, 17 were from wells west of Reserve Street.

The Missoula City-County Health Department (Health Department) and Howard Newman collected a significant amount of water quality data in the Linda Vista subdivisions between 1987 and 1990. The information obtained between 1987 and 1990 was summarized in a report prepared by the Health Department entitled Summary Report for the Linda Vista Area (1992). In the older high density Linda Vista subdivisions, multiple factors combined to cause severe groundwater contamination. During one sampling event conducted by the Health Department in Spring, 1990, 10 of approximately 90 domestic wells were found to be exceeding the drinking water standard of 10 mg/l nitrate-N. Public sewer service has been extended into the area, and as of January, 1996, 164 (94%) of the 180 homes in the older Linda Vista subdivisions have been connected to public sewer. All newer homes in the area are served by public sewer. A network of 11 domestic wells in the Linda Vista area that have exceeded the nitrate-N standard in the past, has been established to monitor improvements in groundwater after the public sewer system is installed.

Kiklighter and Stanford (1985) studied nitrate-N levels in the Bitterroot River. This study located groundwater seeps with elevated nitrates along the east bank of the Bitterroot River between Fort Missoula and the confluence with the Clark Fork River. Water samples collected from these seeps were found to have nitrate concentrations at least 10 times the level found in the Bitterroot River. A seep at Fort Missoula contained 1.34 mg/l nitrate-N, and a seep near the McClay Bridge contained 1.51 mg/l nitrate-N. The Bitterroot River had a concentration of 0.01 mg/l where it passed the Orchard Homes/Target Range area.

Additional sampling by the Water Quality Bureau of the Montana Department of Health and Environmental Sciences has confirmed the contribution of nitrates to the Bitterroot River by groundwater originating from unsewered areas west of Missoula. According to a final report issued by the Water Quality Bureau on phosphorous and nitrogen sources in the Clark Fork River basin, up to half of the soluble nitrogen load in the lower Bitterroot River during the summer is attributable to discharge of contaminated groundwater from the Missoula area (Ingman, 1992).

A study of the carrying capacity of groundwater systems within Missoula County is currently being completed for the Missoula Board of County Commissioners. The study is being completed as a cooperative effort between The University of Montana Geology Department and Land and Water Consulting, Inc..

This project is being completed in three phases. Phases I and II are complete and phase III is nearly complete. In Phase I Land & Water Consulting Inc. compiled data on septic systems and groundwater, prepared an initial Carrying Capacity Model, and ran the model to estimate carrying capacity within the County (Land & Water Consulting Inc., 1995). The data were input into a nitrate dilution model developed by Bauman and Schafer (1984).

Phase II was completed by The University of Montana Geology Department (Woessner et al., 1995). This phase involved the collection of data from existing wells in Condon, Seeley Lake and Frenchtown, and detailed instrumentation of two septic systems in the West Reserve street area (North and South sites) and one in Frenchtown. The septic systems were instrumented with shallow monitoring wells and soil water samplers. Data was collected from these sites to determine how septic system contaminants traveled from the drainfields to the water table, and how the contaminants mixed and moved in groundwater. Mixing depths in groundwater near the drainfields ranged from 7 to 15 feet. The North and South sites both consisted of drainfield systems installed in coarse sands and gravels over shallow groundwater.

At the North site, groundwater was measurably impacted with chlorides from a water softener. Fecal coliform bacteria were detected in groundwater under the drainlines. The results also documented low dissolved oxygen levels (anaerobic conditions) and ammonia within the top three feet of the aquifer during high water in June. Water level monitoring also showed that the water table rose to within five feet of the surface during seasonal high water, showing that the system does not meet current Health Code standards. The report states that elevated nitrate-N levels in groundwater, the presence of ortho-phosphate, high chloride levels and low levels of dissolved oxygen all imply rapid infiltration of waste to the water table Woessner et al. (1995).

At the South site, the water level was also shown to rise to within five feet of the surface. Ortho-phosphate was detected in groundwater under the drainfield, along with low dissolved oxygen levels and fecal coliform bacteria. The domestic well for this was sample six times and tested positive for fecal coliform bacteria twice. Coliphage and a human enteric virus were also detected in groundwater under the septic system at this site. Rapid infiltration of waste to the water table was also noted at this site. The Frenchtown site, which was in an area of finer grained sands and gravels, and deeper groundwater showed better treatment of septic system waste.

Phase III, which is being completed by Land & Water Consulting Inc., will use the results of Phase I and Phase II to refine the Carrying Capacity Model.

The limited virus sampling conducted during Phase II of the Carrying Capacity Study resulted in refinement of groundwater viral sampling techniques and development of the ability to analyze groundwater samples locally for viruses. In general, isolating viruses from groundwater is very difficult, and only a few laboratories in the United States perform routine analysis for viruses in groundwater samples (Woessner et al., 1995).

Dr. Bill Woessner, University of Montana Geology Department and Dr. Dan DeBorde, University of Montana Division of Biological Sciences have teamed up to develop the field and laboratory techniques needed to collect groundwater samples and conduct the virus analysis locally. As a result of this work, three important studies are currently underway in the Missoula area to determine the fate and transport of viruses in groundwater.
One project is looking at the fate and transport of viruses around a pumping

well (DeBorde and Woessner, 1994b). This study proposes to construct a production well at a controlled site and then inject attenuated polio virus into the groundwater around the well. The well will then be pumped and samples will be collected for analysis to determine the presence of viruses. The attenuated poliovirus used in this study is similar to that used in polio vaccine, and its use will not pose a public health threat.

Another study involved analysis of samples from two existing public water supply wells. The wells were sampled monthly for one year. Preliminary results indicate that none of the samples collected contained active human enteric viruses, but one positive sample was obtained which contained male specific coliphage virus (MS2) (DeBorde, 1996, personal communication). Coliphage viruses are viruses that infect coliform bacteria.

A third project is underway at Frenchtown High School (DeBorde and Woessner, 1994a). The septic system at the high school has been instrumented with a network of monitoring wells. Fieldwork is underway to determine travel times and travel distances for coliphage bacteria. Preliminary results from this research have shown that coliphage viruses traveled 21 feet in groundwater within 48 hours of being injected into the aquifer up-gradient, and viruses were detected 82 feet away from the point of injection within 500 hours of injection into groundwater (DeBorde, 1996, personal communication). These results are preliminary, and a final report has not been published.

2.3 OTHER RELATED STUDIES

Contamination of groundwater by septic systems in the Evergreen, Montana area was documented by King (1988). Homes in the Evergreen area are built over a highly transmissive, unconfined aquifer. The depth to groundwater is 6-12 feet. The septic systems were found to be only 60% efficient for removal of total nitrogen and 70% efficient for removal of total phosphorus. Some of the groundwater samples collected exceeded the drinking water standard for nitrate-N of 10 milligrams per liter (mg/l).

A study of nitrate trends in the Helena Valley was completed by the Lewis and Clark County Water Quality District (Drake, 1995). The study included analysis of samples from 77 wells. The wells had previously been sampled in 1990 (Drake, 1991). The study concluded that the average nitrate concentration in the valley increased 2.5% between 1990 and 1994. During the same period, septic system installations increased by 26%. The study also concluded there was a correlation between nitrate-N levels and septic system density.

3.0 SEPTIC SYSTEM CHARACTERISTICS

The quantity of wastewater disposed of into a residential septic system varies with the number of residents, the type of occupancy (permanent vs seasonal) and types of plumbing fixtures and appliances used in the home. The average daily discharge of wastewater from a typical residential dwelling is 44 gal/capita/day (EPA, 1980). This value was obtained from weighted averages of 9 studies involving 109 households. For a typical family of four this would equal 176 gallons of wastewater/day per household. The Missoula County Carrying Capacity Study and the State Water Quality Division are using 200 gallons/day as the average wastewater flow from a typical single family home.

The types of appliances used in the home can affect the quality of wastewater disposed of into a septic system. In addition to normal sanitary waste, the two most common appliances that can alter wastewater quality are garbage disposals and water softeners. Garbage disposals increase the amount of solid organic material entering the septic system. Backwash/regeneration wastewater produced from water softeners adds significant quantities of salts and metals to the septic system. In addition home hobby or home business activities such as furniture refinishing and photographic processing can generate wastewater contaminated with solvents and heavy metals.

3.1 TYPES OF SEPTIC SYSTEMS AND TREATMENT CAPABILITIES

Once wastewater is discharged to a septic system, the level of treatment received determines the quality of the wastewater that reaches groundwater. The factors affecting treatment prior to discharge to groundwater include the type of septic system, soils, properties of the sediments in the zone between the soil horizon and the water table (vadose zone), and the depth to the water table. The fate and transport of septic system contaminants that reach the water table depends on the flow characteristics of the aquifer and the physical and biological properties of the sediments and groundwater in the aquifer. The type of septic system controls the initial quality of wastewater discharged to the environment. The three common types of septic systems used in the Missoula area are the cesspool, seepage pit and drainfield. In addition, there are several types of alternative septic systems.

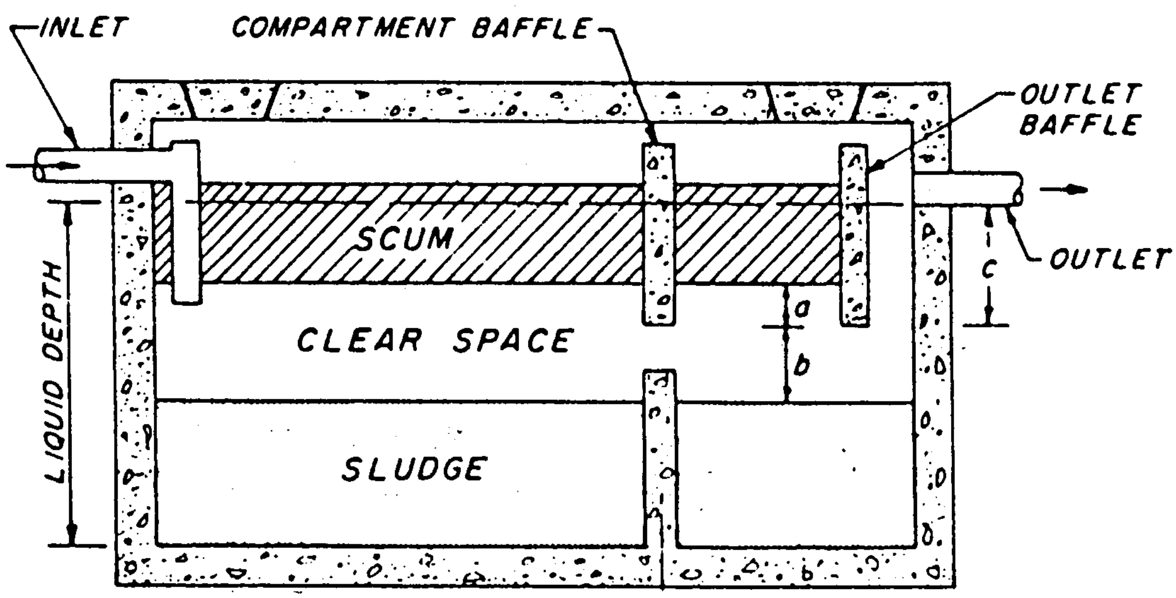
3.1.1 Septic Tanks

Septic tanks provide pretreatment of domestic wastewater prior to discharge into a soil absorption system. The septic tank separates solids and liquids, and traps settleable solids and floatable solids. Within a septic tank, raw sewage undergoes physical and biochemical transformations. Facultative anaerobic bacteria (bacteria that can live with or without free oxygen) break down organic material in the septic tank. These bacteria consume any available oxygen, so the atmosphere in the tank is anaerobic (oxygen depleted). Four distinct layers are formed in a typical septic tank, as shown in Figure 1. Solids settle to the bottom to form a sludge layer. A liquid layer forms above the sludge, which becomes the effluent from the tank. Grease,

fat and other materials float to the top of the liquid layer to form a layer of floating scum. Above the scum layer gases such as carbon dioxide, hydrogen sulfide and methane collect to form the fourth layer.

In the septic tank some solid organic matter that accumulates on the bottom of the tank is converted by facultative anaerobic bacteria into liquid organic matter, water, ammonia, methane, carbon dioxide and hydrogen sulfide. The remainder of the solid material in the tank is not degraded and must be periodically pumped out. This remaining solid material is referred to as septage sludge. The gases produced by decomposition dissolve into the wastewater or rise to the top of the tank. The anaerobic degradation process in the septic tank is incomplete, and wastewater leaving the septic tank contains suspended solids, liquid organic matter and dissolved gases. Once the wastewater leaves the septic tank, further treatment depends on whether the environment it is released to is aerobic or anaerobic (with or without oxygen). If the wastewater is disposed of into a cesspool or seepage pit, the environment will be anaerobic. This is an important limitation, because wastewater discharged into an anaerobic environment is limited in its further treatment.

FIGURE 1
Fluid layers in an operating septic tank.



3.1.2 Cesspools

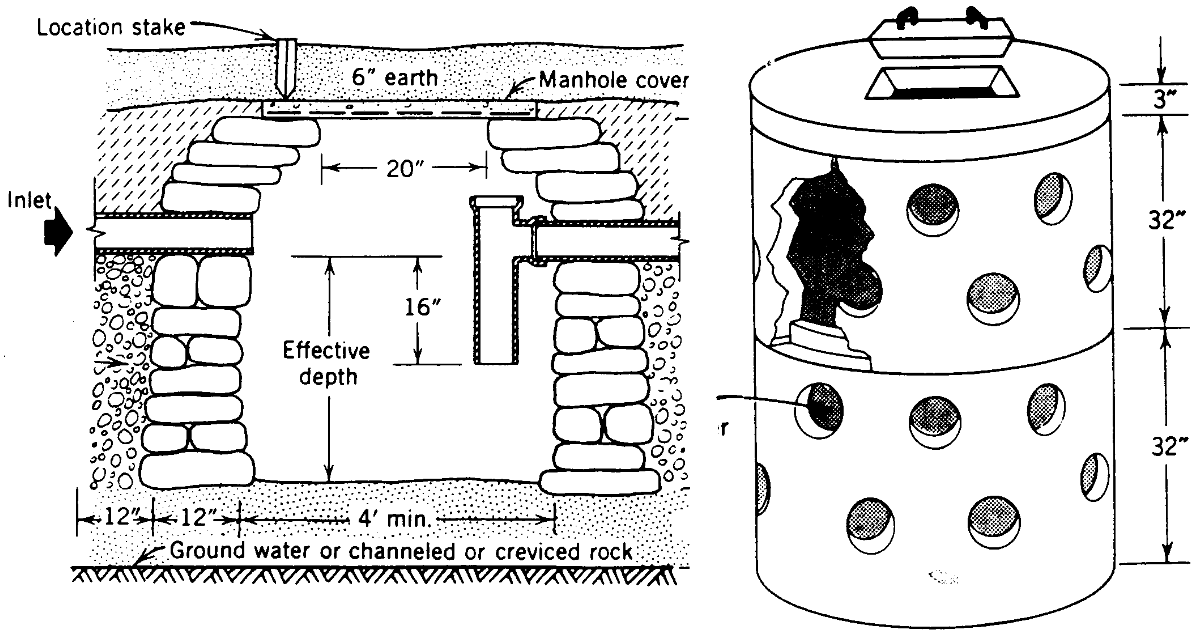
A cesspool is simply an excavated hole or pit in the ground used to dispose of raw sewage. A septic tank is not included, so there is no pretreatment of the wastewater prior to discharge into the ground. The cesspool is the crudest form of a septic system, but they are still being used by some older homes in the Missoula area. Older cesspools often were constructed of hand-rocked pits 3 to 6 feet in diameter and up to 20 feet deep.

Cesspools are outdated systems which tend to plug easily, except in very porous soils, due to the amount of solids disposed of directly into the system. They also provide very little treatment of wastewater. Treatment is limited because the raw sewage is discharged below the organic soil horizon, the contact area with the sediments around the cesspool is small, the environment inside the cesspool is anaerobic (without oxygen) and the separation between the bottom of the cesspool and the water table is reduced by the depth of burial. Cesspools are not allowed under the current Missoula City-County Health Code, and have been prohibited since 1967.

3.1.3 Seepage Pits

A seepage pit is basically a cesspool with a septic tank installed to provide pretreatment of the wastewater prior to discharge into the cesspool structure. Figure 2 shows schematics of a typical hand rocked cesspool, and a precast concrete seepage pit structure. Seepage pits provide better treatment than a cesspool due to the physical and biochemical pretreatment that occurs in the septic tank. Once the wastewater enters the seepage rings, treatment is limited by the same factors that limit treatment in a cesspool (no organic soil contact, limited sediment contact, anaerobic conditions and reduced separation between the system and groundwater). Construction of the seepage pit may be similar to a cesspool, or it may be constructed of concrete seepage rings which are typically 6 feet in diameter and buried from 3 to 20 feet. The concrete walls are perforated and the bottom is open. The area around the seepage rings may be packed with gravel. Under the Missoula City-County Health Code, seepage pits are only allowed as replacement systems if there is no room for a drainfield and a 25 foot separation between the bottom of the seepage pit and the water table can be maintained. A 4 foot separation from groundwater is allowed if public sewer service is expected to be available within 10 years.

FIGURE 2
Schematics of a cesspool and seepage pit, Salvato (1992)



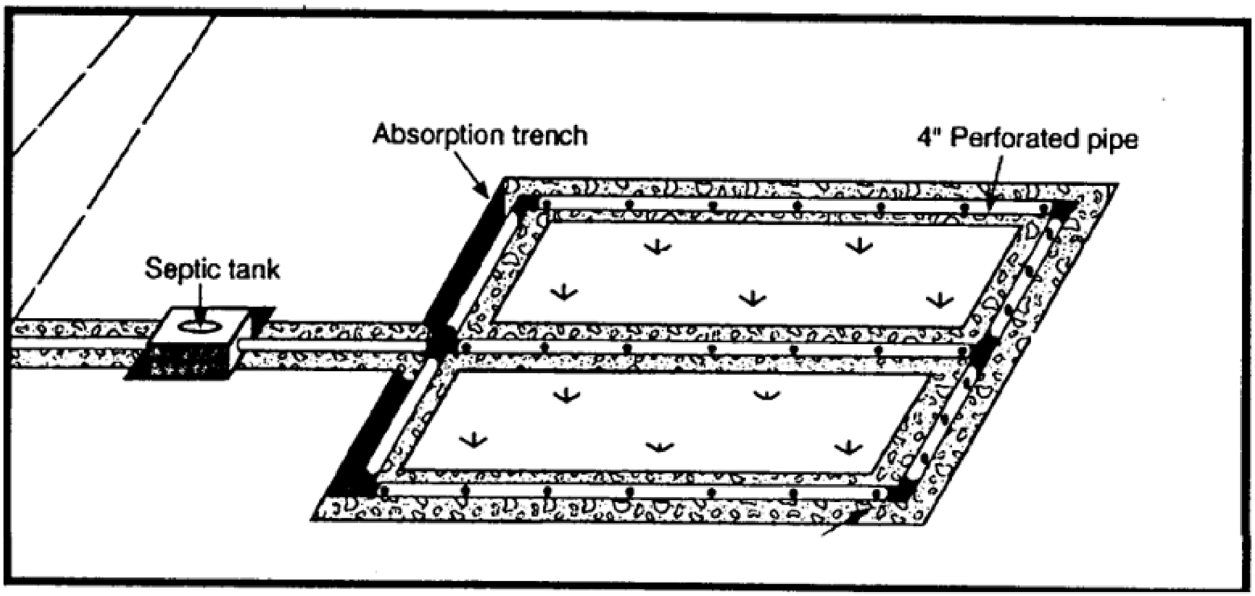
Cesspool **Seepage pit**

3.1.4 Drainfield Systems

The highest level of conventional septic system treatment is provided by the drainfield system. The only type of conventional septic system currently allowed in Missoula County is the septic tank with a drainfield. A septic system utilizing a drainfield can be viewed as consisting of four treatment stages, consisting of the septic tank, the drainfield, the soil zone and the groundwater system (Woessner et al., 1995). The septic tank provides initial pretreatment of raw sewage in an anaerobic environment, prior to discharge of the wastewater to the drainfield. The drainfield distributes the pretreated wastewater within the shallow soil zone for further treatment in an aerobic environment. Figure 3 shows a schematic of a septic tank and drainfield.

The soils provide physical filtration and a media in which biochemical processes can continue. The final treatment stage is dispersal of the treated wastewater in the groundwater system. Under the proper conditions these treatment stages are sufficient to protect groundwater. If septic system densities are too high, septic tanks are not maintained, drainfields are improperly installed, soils under the drainfield are coarse, or the water table is shallow, the treatment stages will not provide sufficient treatment and groundwater degradation may occur.

FIGURE 3
Schematic of a septic tank and drainfield system.



3.1.5 Alternative Septic Systems

Several alternative septic systems are available for use on sites with restrictive environmental features, such as shallow groundwater or bedrock. Some systems are also being evaluated for use in small communities with high rates of septic system failures or water pollution problems, which lack access to centralized sewage collection and treatment facilities. These alternative septic systems are not in widespread use currently in the Missoula Valley, principally due to high costs and maintenance requirements, relative to conventional septic tank/drainfield systems.

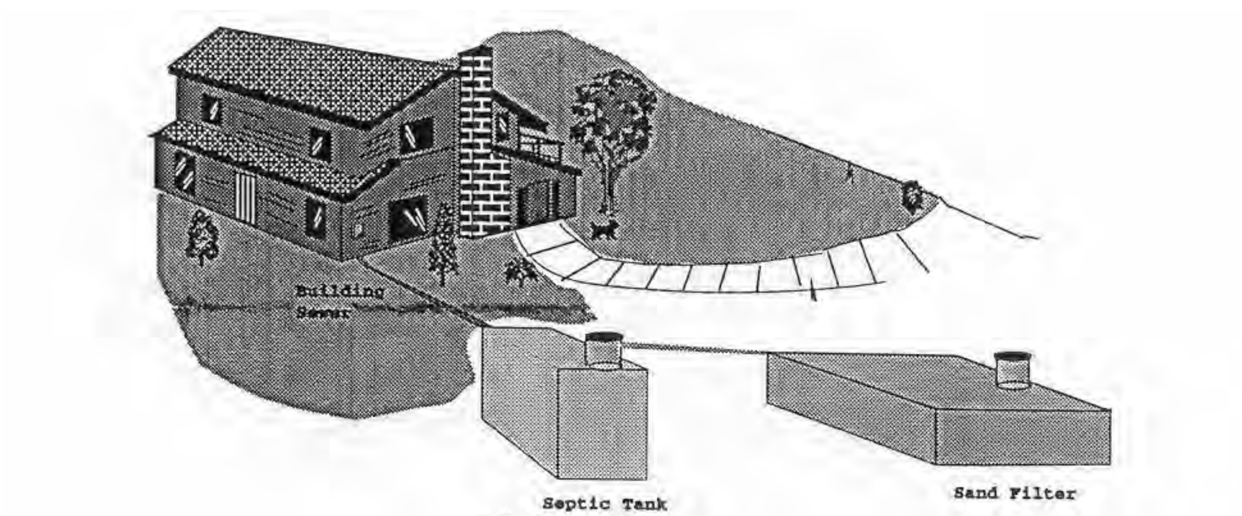
It is beyond the scope of this project to comprehensively evaluate the suitability and cost of these systems for use in Missoula Valley unsewered areas, as an alternative to the provision of a centralized sewage collection and treatment system. However, a brief summary of three alternative systems is provided for background. Each of these systems is currently approved for use by the Montana Department of Environmental Quality. Only the sand mound system is currently approved in Missoula County. Each of the systems uses a drainfield system, they are not approved for use with cesspools or seepage pits.

Sand Filters;
A sand filter is used to treat effluent from the septic tank prior to discharge to a conventional drainfield (see Figure 4). A sand filter consists of several layers of sand located under or above ground. Pumps distribute effluent evenly, or periodically dose effluent, into the sand filter. A dosing septic tank is required in place of or following a conventional septic tank, to house the pumps that distribute effluent to the sand filter. Some systems recirculate effluent after it

percolates through the sand filter to receive additional treatment. Naturally occurring bacteria in the sand filter reduce contaminants in the effluent. Some systems include a disinfection process to eliminate some pathogens before discharge, this is used in some states where the systems discharge directly to surface water.

Sand filters have been determined to meet the Montana Department of Environmental Quality definition of level two septic system treatment, which requires 60% nitrogen removal. The Department requires certain monitoring be performed quarterly for such systems to ensure performance. One manufacturer of intermittent sand filters reports average effluent nitrogen concentrations of 30 mg/l, and average fecal coliform levels of 400 organisms per 100 ml (Ball, 1995).

FIGURE 4
Intermittent sand filter system



Sand filters could be used in unsewered areas where lots are large enough to accommodate them. In such a setting, a sand filter would be installed following the septic tank to treat effluent prior to discharge to the drainfield. In areas of high density, lot sizes may not accommodate the addition of a sand filter. In many of the Missoula Valley's high density unsewered areas, cesspools or seepage pits are currently in use. Where a cesspool or seepage pit is used rather than a conventional drainfield, a sand filter may not provide adequate treatment prior to discharge to the seepage pit. High strength wastewater, from a restaurant, supermarket or other commercial facility, must be pretreated prior to discharge to a sand filter.

Intermittent sand filters used for single-family homes range in cost from $5,000 to $10,000 (Orenco Systems, 1993). However, sand filters require continued maintenance, monitoring and eventual replacement when they fail. If used throughout an unsewered area as an alternative to centralized sewage collection and treatment, a Special Improvement District (SID) may be required to ensure the systems are adequately maintained and replaced, and to protect public health. Sand filters must be designed by a professional engineer. Installers of such systems require additional training in order to become certified in Missoula County.

Sand Mounds;
Mound systems, sometimes known as Wisconsin or Nodak mounds, are similar to sand filters, but are constructed above ground in areas where the water table or bedrock is too close to the ground surface to allow use of a conventional drainfield system. A cross section of an elevated sand mound is shown in Figure 5. Elevated sand mounds are currently permitted in Missoula County only for the purpose of maintaining separation from the drainfield and high seasonal groundwater, bedrock or impermeable layers where these limiting layers are less than six feet from the natural ground surface. Pressure distribution is required, as in a sand filter, to distribute effluent evenly within a mound. Mound systems must be designed by a professional engineer and installed by a person certified for such installations. The Montana Department of Environmental Quality classifies elevated sand mounds as level two septic system treatment, which requires 60% nitrogen removal. The Department requires certain monitoring be performed quarterly for such systems to ensure performance. Space limitations could preclude use in high-density, unsewered areas.

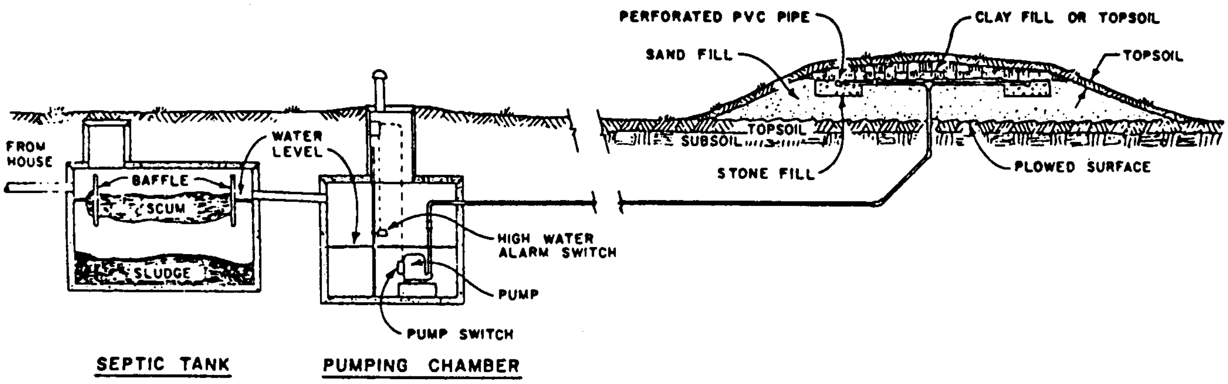
Aerobic septic tanks;
Aerobic septic tanks mix air and wastewater, allowing oxygen-using bacteria to grow and aid in the digestion and treatment of wastewater. These septic tank systems are sometimes called aerobic package plants. The effluent from the home first enters a settling chamber where some anaerobic treatment occurs and solids settle to the tank bottom. Effluent then flows into a chamber equipped with an electrically powered aerator. A cut away view of a aerobic septic tank is shown in Figure 6.

Aerobic package plants are used in place of a conventional septic tank. Because they incorporate both an anaerobic and an aerobic treatment process within the tank, they provide better treatment than a conventional septic tank. Effluent from the aerobic tank is disposed into a drainfield. An optional disinfection system may be added to aerobic package plants.

The Montana Department of Environmental Quality classifies some aerobic package plants as level two septic system treatment, which requires 60% nitrogen removal. Not all systems meet this requirement. The Department requires certain monitoring be performed quarterly for such systems to ensure performance. Treatment capability for pathogens is unknown.

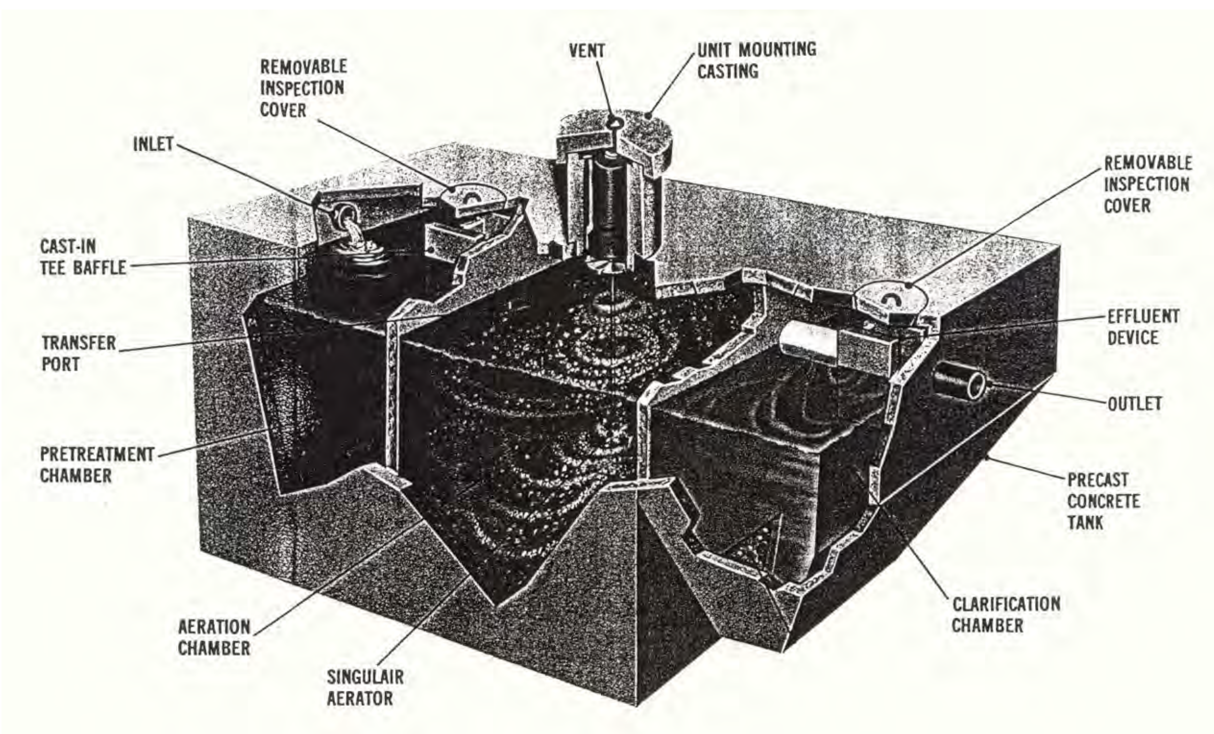
Maintenance of aerobic package plants is essential for performance. Insulation or heating may be required to ensure adequate treatment performance during periods of very cold weather.

FIGURE 5
Elevated sand mound cross section



Source: Canter and Knox, (1985), after Harkin et al., (1979)

FIGURE 6
Aerobic septic tank system



Source: Norweco, Norwalk wastewater equipment company

Aerobic package plants could be used in unsewered areas to provide improved wastewater treatment. An aerobic tank would be installed in place of or following a conventional septic tank to treat effluent prior to discharge to the drainfield. In areas of high density, lot sizes may not accommodate the use of a drainfield. In many of the Missoula Valley's high density unsewered areas, cesspools or seepage pits are currently in use. Where a cesspool or seepage pit is used rather than a conventional drainfield, an aerobic package plant may not provide adequate treatment prior to discharge to the seepage pit. High strength wastewater, from a restaurant, supermarket or other commercial facility, may require pretreatment prior to discharge to an aerobic package plant.

Aerobic package plants used for single-family homes cost about $5,000 plus installation. These systems require continued maintenance and monitoring. If used throughout an unsewered area as an alternative to centralized sewage collection and treatment, a Special Improvement District may be required in order to ensure that such systems are adequately maintained and replaced, and to protect public health.

3.2 TYPICAL CHARACTERISTICS OF SEWAGE AND SEPTIC TANK EFFLUENT

Wastewater leaving a septic tank still needs treatment prior to discharge to groundwater. Wastewater leaving the tank contains suspended sediment, high biochemical oxygen demand (BOD), nitrogen, phosphorous, non-pathogenic bacteria and viruses and sometimes pathogenic bacteria and viruses. The following sections describe the characteristics of influent wastewater entering septic systems, effluent wastewater discharged from septic systems, and the fate of the main contaminants once they enter the subsurface from a septic system using a drainfield.

The characteristics of residential sewage have been documented by many authors. Table 3 shows average concentrations of selected contaminants in residential wastewater compiled from several studies by the U.S. Environmental Protection Agency (EPA 1980).

TABLE 3
Characteristics of typical residential wastewater

PARAMETER	MASS LOADING gm/cap/day	CONCENTRATIO N RANGE mg/l	AVERAGE CONC. mg/l
Total Solids	115-170	680-1000	840
Volatile Solids	65-85	380-500	440
Susp. Solids	35-50	200-290	245
Vol. Susp. Solids	25-40	150-240	195
BOD_5	35-50	200-290	245
COD	115-125	680-730	705
Total Nitrogen	6-17	35-100	67
Ammonia	1-3	6-18	12
Nitrite+Nitrate	<1	<1	<1
Total Phosp.	3-5	18-29	23
Phosphate	1-4	6-24	15
Total Coliform*	N/A	10^{10}-10^{12}	10^{11}
Fecal Coliform*	N/A	10^{8}-10^{10}	10^{9}

* Concentration in organisms per liter.

Source: U.S. EPA, Oct. 1980, Design Manual, Onsite Wastewater Treatment and Disposal Systems.

Local studies have also documented the characteristics of septic system effluent. Woessner et al., (1995) sampled septic tank effluent from systems in the Missoula urban area. Table 4 summarizes the data from Woessner et al., (1995). Nitrogen in the septic tank effluent is present mainly as ammonia.

In addition to the characteristics listed in Table 4, there are a large number of pathogenic microorganisms that may be present in sewage. Table 5 lists some common water borne diseases and the bacteria responsible for illnesses. All of these bacteria may be present in septic tank effluent. Table 6 lists some important viruses and bacteria that can be transported from a septic system, through the unsaturated zone to groundwater.

TABLE 4
Characteristics of septic tank effluent in Missoula

SITE	DISS. OXYGEN	AMMONIA	NITRATE	CHLORIDE	ORTHO PHOS.	FECAL COLIFORM
NORTH	0.5*	26.4	<0.5	413.3	3.1	TNTC**
SOUTH	0.2	40.1	<0.5	27.0	10.2	644,700
FRENCH-TOWN	2.0	24.0	<0.5	19.6	5.1	224,000
AVERAGE	0.9	30.1	<0.5	153.3	6.1	N/A

*All concentrations are in mg/l except for fecal Coliform which is reported as colonies per/100ml. Source: Woessner et al., (1995).

**(TNTC) Too Numerous To Count

TABLE 5

Common water borne diseases and causative agents that may be present in septic system effluent

DISEASE	SPECIFIC AGENT
Salmonellosis	Salmonella typhi
Typhoid Fever	Salmonella typhosa
Paratyphoid Fever	Salmonella paratyphi
Bacillary Dysentery	Shigella spp.
Cholera	Vibrio cholera
Camplyobacter enteritis	Campylobacter jejuni
Traveler's Diarrhea	Enteropathogenic E. coli

Source: Modified from Salvato (1992)

TABLE 6
Human pathogens that may be transported through the unsaturated zone to groundwater

Microorganism (size range)	Disease
VIRUSES	
Adenoviruses	Respiratory disease
Polioviruses	Poliomyelitis
Echoviruses	Meningitis
Coxsackie viruses	Myocarditis, meningitis
Hepatitis A virus	Infectious hepatitis
Rotaviruses	Diarrhea
BACTERIA	
Campylobacter fetus	Diarrhea
Escherichia coli (pathogenic)	Diarrhea
Salmonella typhi	Typhoid fever
Vibrio cholera	Cholera
Shigella spp.	Bacillary dysentery

Source: Modified from Powelson and Gerba (1995)

3.3 FATE AND TRANSPORT OF SEPTIC SYSTEM CONTAMINANTS

The primary contaminants that may enter groundwater from a septic system include viruses, bacteria, nitrogen (mainly nitrate), phosphorus (phosphate), chlorine (chloride) dissolved metals and organic chemicals. The fate and transport of these contaminants in the unsaturated zone (vadose zone) and the saturated zone (groundwater) varies. In general the transport of contaminants through the vadose zone is more complex than transport in groundwater because the vadose zone also contains gas phases (air). A general review of the important factors controlling movement of septic system contaminants is presented below.

Bacteria;
The transport of bacteria in groundwater is controlled by both physical and biological processes. Bacteria may be physically filtered from groundwater if the sediment is fine grained. The size of bacteria range from 0.2 to 5.0 microns. According to Vance (1995), if bacteria are less than half the size of

the entrances to pore spaces in the sediment, mechanical filtration will not be effective. Vance (1995) provides data on the pore entrance sizes for various sediment types. The pore entrance size in fine to coarse grained silt is 0.7 to 7 microns. Compared to the size range for bacteria (0.2 to 5.0 microns), pore entrance sizes in silts are small enough to mechanically filter bacteria. The pore entrance size for fine to coarse grained sands range from 24 to 240 microns, and for fine to coarse grained gravels, 720 to 7,200 microns (Vance, 1995). Even the largest bacteria are much less than half the pore entrance sizes for sediments ranging from fine sands to coarse gravels. Based on these pore entrance sizes and the general rule that bacteria less than half the pore entrance size generally will not be mechanically filtered from the sediment, mechanical filtration may be effective in clays and silts, but probably is a less important removal process in sands and gravels.

Another important physical process that may remove bacteria from groundwater is adsorption (attachment to the surface of soil particles). Bacteria have an overall negative charge on their surface, so they may be attracted to sediment particles that have a positive charge. Once bacteria are adsorbed on sediment particles by electrostatic forces, they may produce sticky binding substances referred to as exopolymers, that help hold them to the sediment particles.

Biological factors control the survival of bacteria in soils and groundwater. The environmental factors that control the survival of enteric bacteria in soil are listed in Table 7. If the soil conditions allow for survival and transport of bacteria to the water table, groundwater contamination will occur.

Bacteria that reach the water table may survive for long periods of time and be transported great distances if the physical factors and survival conditions are right. Table 8 shows some reported survival times for pathogenic organisms in groundwater. Locally the transport of bacteria in groundwater has been documented by Ver Hey (1987) and Woessner et al. (1995) under septic system drainfields in the Missoula Valley. They have shown that fecal coliform bacteria from septic systems do reach groundwater.

In a study of septic systems in the Orchard Homes area of Missoula, Ver Hey (1987) stated that "There is no doubt, from the data, that fecal coliform are moving from the drainfield through the vadose zone and are being carried along in the aquifer flow.". She documented fecal coliform bacteria 50 feet from the drainfield in groundwater. Fecal coliform bacteria were also found in groundwater samples collected by Woessner et al (1995) from the North and South Missoula sites. Both these sites have drainfields installed in coarse sands and gravels. Fecal coliform bacteria were not found in groundwater samples obtained from the Quarter Mile site in Frenchtown, where the drainfield is installed in sand.

TABLE 7
Environmental factors affecting survival of enteric bacteria in soil

FACTOR	COMMENTS
Moisture content	Greater survival time in moist soils and after heavy rainfall.
Moisture Holding Capacity	Survival time shorter in sandy soils than in soils with high water holding capacity.
Temperature	Survival time is higher at low temperatures and in winter.
Ph	Survival time is longer in alkaline soils.
Sunlight	Survival time is shorter at soil surface due to ultraviolet light.
Organic Matter	Survival time is longer when the concentration of organic matter is higher in the soil.
Antagonism from soil microflora	Survival time is longer in sterile soils.

Source: Canter and Knox (1985)

TABLE 8
Survival times of pathogenic organisms in groundwater

Organism	Survival,Groundwater
Salmonella paratyphi	60-70 days
Salmonella typhi	8-23 days
Shigella	10-35 days
Coliform bacteria	7-8 days
E. Coli.	10-45 days
Viruses (polio, hepatitis entero)	16-140 days

Source: Modified from Salvato (1992)

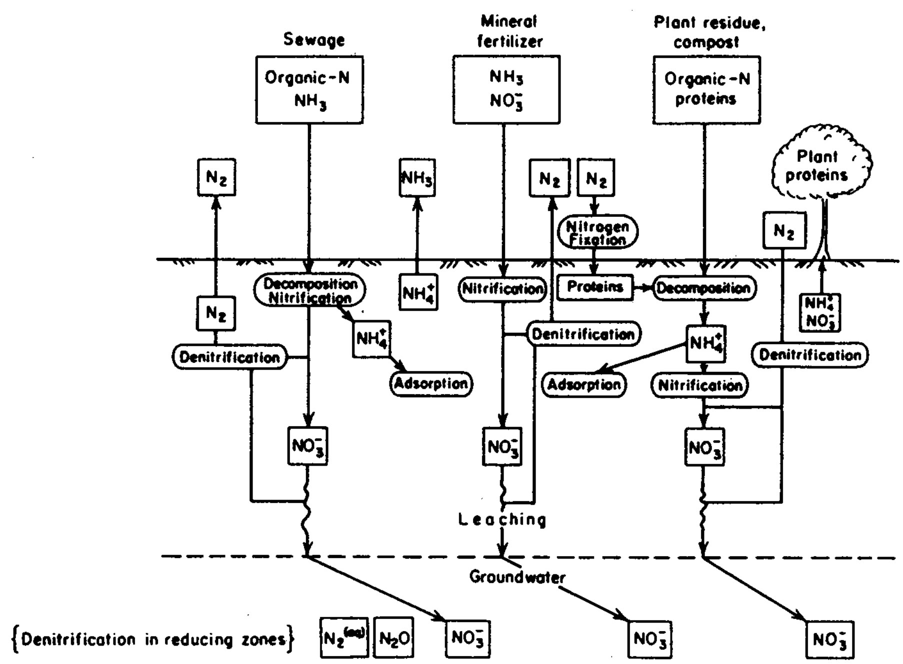
Viruses;

Viruses are much smaller than bacteria and range in size from 0.005 to 0.1 microns. Because they are much smaller than bacteria, mechanical filtration of viruses in groundwater is not a primary removal mechanism. Virus removal in soils and groundwater is believed to be mainly due to adsorption (Bitton and Gerba, 1985). The work currently being completed by Dr. DeBorde and Dr. Woessner from the University of Montana (see Section 2) will provide local information on the fate and transport of viruses in the Missoula Valley Aquifer. The documented outbreaks of groundwater borne disease caused by viruses, presented in section 2, demonstrates the ability of viruses to move in groundwater.

Nitrogen;

Dissolved nitrogen in the form of nitrate (NO_3^-) is the most common contaminant identified in groundwater (Freeze and Cherry, 1979). It is often used to evaluate the impacts of septic systems on groundwater. Other forms of nitrogen include ammonium (NH_4^+), ammonia (NH_3), nitrite (NO_2^-), nitrogen gas N_2 and organic nitrogen. Nitrogen, present in raw sewage, undergoes transformations as it moves through the septic system and enters the groundwater system. Good reviews of nitrogen transformations are provided by Sikora and Corey (1975), Canter and Knox (1985) and Freeze and Cherry (1979). Figure 7 shows the possible forms and fate of nitrogen compounds from sewage and other sources.

FIGURE 7
Form and fate of nitrogen in the subsurface



Source: Freeze and Cherry, (1979)

Nitrogen in residential wastewater discharged to a septic tank (influent) is present mainly as organic nitrogen (75%) and ammonium (25%). In the septic tank, where conditions are anaerobic (low in oxygen), organic forms of nitrogen are converted to ammonium through a process referred to as ammonification. Effluent leaving the septic tank consists of organic nitrogen (25%) and ammonium (75%) (Sikora and Corey, 1975). Total nitrogen concentrations remain about the same, so septic tanks are ineffective at removing nitrogen, but they do convert organic nitrogen to ammonium (Canter and Knox, 1985).

Once the septic tank effluent is discharged to the subsurface, additional nitrogen transformations occur. Assuming a drainfield system is used, the remaining organic nitrogen is converted to ammonium in the subsurface. The ammonium ions, which have a positive charge, are initially adsorbed onto soil particles which have a negative charge. If sufficient oxygen is present in the soils, the ammonium ions will be oxidized to nitrate through a process referred to as nitrification ($NH_4^+ > NO_2^- > NO_3^-$). This process is dependent on good aeration of the soils. If the soils are poorly drained, saturated, anaerobic conditions may occur around the drainfield, and only partial nitrification may occur. Incomplete nitrification can also occur if the soils are very coarse and the water table is shallow. In this case, the effluent reaches groundwater before the nitrification process is complete, and ammonium and nitrate may be present in groundwater.

Once nitrogen is transformed to nitrate, it may travel with the effluent to groundwater, be taken up by plants above the drainfield, be reduced again by bacteria or undergo denitrification, which is also mediated by bacteria. Uptake by plants is indicated by lush growth over the drainfield area, but this uptake of nitrogen is considered to be minor because the amount of nitrogen being produced by the septic system is much greater than the amount used by the plants, and because eventually the plants decompose and release organic nitrogen back into the soils Sikora and Corey (1975). Reduction of nitrate by bacteria can be by dissimilatory nitrate reduction, where the bacteria use the nitrate as an electron acceptor, without incorporating the nitrogen into biomass, or assimilatory reduction, where the bacteria obtain energy from the nitrate reduction and use the nitrogen to build biomass.

The significance of dissimilatory and assimilatory nitrate reduction as a removal mechanism for nitrate was not determined based on the literature reviewed. Finally, nitrate may be reduced through a process called denitrification ($NO_3^- > N_2O > N_2$). In this case, nitrate is reduced under anaerobic conditions to nitrogen gas, which escapes to the atmosphere. For this reaction to occur, the nitrogen must first be oxidized to nitrate, and then encounter anaerobic conditions, where denitrifying bacteria use the nitrate as an electron receptor during decomposition of other organics.

The water quality sampling conducted by Ver Hey (1987) in the Orchard Homes area supports the traditional view of nitrate behavior. Ver Hey found that nitrate was not being removed in the soils below the drainfields, and that dilution in groundwater was the only source of nitrate reduction. Results of Phase II of the Missoula County Carrying Capacity study (Woessner et al., 1995), however, indicate that nitrate concentrations in groundwater may be reduced by other factors in addition to dilution. They looked at the concentrations of nitrate and chloride in groundwater at increasing distances from drainfields, and found that nitrate concentrations decreased faster than chloride concentrations. Chloride is also assumed to be non-reactive, so if dilution is the main source of chloride and nitrate reduction in groundwater, the concentrations should decrease at the same rate. One possibility is that the nitrate is undergoing assimilatory reduction and is being used by native bacteria present in the groundwater system to build cell structures. The significance of Woessner's findings is that if nitrate is being removed from the groundwater system, the use of nitrate levels as a sole indicator of the presence of sewage in groundwater may be underestimating the impacts from septic systems.

Phosphorus;

The majority of total phosphorus entering a septic system (influent) is in the form of organic compounds containing phosphorus. Most of the phosphorus is converted in the septic tank to soluble orthophosphate (Canter and Knox, 1985). The average concentration of total phosphorus in the effluent from a septic tank is 15 mg/l.

Phosphorus is usually not a groundwater quality concern because it is easily adsorbed on sediment particles and forms insoluble aluminum, iron and calcium phosphate compounds in soils. In alkaline soils containing calcium, insoluble calcium phosphate (hydroxyapatite) formation is the most common removal mechanism. Phosphorus breakthrough can occur, depending on the absorption capacity of the soils and depth to groundwater. In cases where septic systems are installed over shallow groundwater, contamination may occur (Peavy, 1987, and Woessner et al., 1995)). Contamination of groundwater with phosphorus from septic systems in Evergreen, Montana was documented by King (1988). The Evergreen area, near Kalispell, is also in an area of shallow groundwater.

Chlorides;

Chlorides in groundwater can be a useful indicator of septic system contamination if other sources of chloride are not present or can not be quantified. For this study chloride levels were not measured because there are other potential sources of chloride, including the use of road salt, liquid deicers and water softeners, which could not be quantified.

Chloride ions have a negative charge, so they do not tend to adsorb onto soil particles which also tend to have a negative charge. Chloride also does not usually combine with other compounds in groundwater. It tends to be non-reactive and travel with groundwater. Chloride concentrations in septic tanks vary, and homes using water softeners can contribute higher concentrations of chloride to groundwater. The North Missoula study site, monitored by Woessner et al. (1995), which has a water softener, had chloride levels in groundwater under the septic system as high as 437 mg/l. By contrast, chloride levels monitored in groundwater at the South Missoula site, which does not have a water softener, never exceeded 10 mg/l under the drainfield. In general, septic systems provide no treatment for chloride and the primary treatment mechanism available is dilution in groundwater. In addition, water softeners connected to septic systems can contribute significant quantities of chloride to groundwater.

Metals;
Heavy metals are present in septic system effluent at low levels unless non-sanitary wastes such as photographic processing fluids are disposed of into the septic system. The transport of heavy metals from septic systems in soils and groundwater is very complex. Heavy metals do not all behave the same. In general, there are four major processes that can fix heavy metals in soils and aquifer sediments. These processes are adsorption, chemical reaction with other compounds, electrostatic attraction to soil particles (ion exchange) and chemical precipitation. The primary mechanism for fixing heavy metals in soils is adsorption (Canter and Knox, 1985). One concern related to septic systems is that heavy metals may be mobilized by other contaminants in sewage. Arsenic, mercury, nickel, copper and cadmium may be more soluble in the presence of phosphates and chlorides (Canter and Knox, 1995) or organic matter.

Overall Level of Treatment;
Treatment of sewage by septic systems is usually determined by sampling effluent from the drainfield and comparing the results with water samples collected from various depths in the unsaturated zone and in groundwater below the drainfield. This type of analysis was completed by Woessner et al. (1995) for Phase II of the Carrying Capacity study. Figure 8 shows a typical instrumentation used for Phase II of the Carrying Capacity study.

FIGURE 8
Cross section showing instrumentation used for the Carrying Capacity Study (from Woessner et al., 1995)

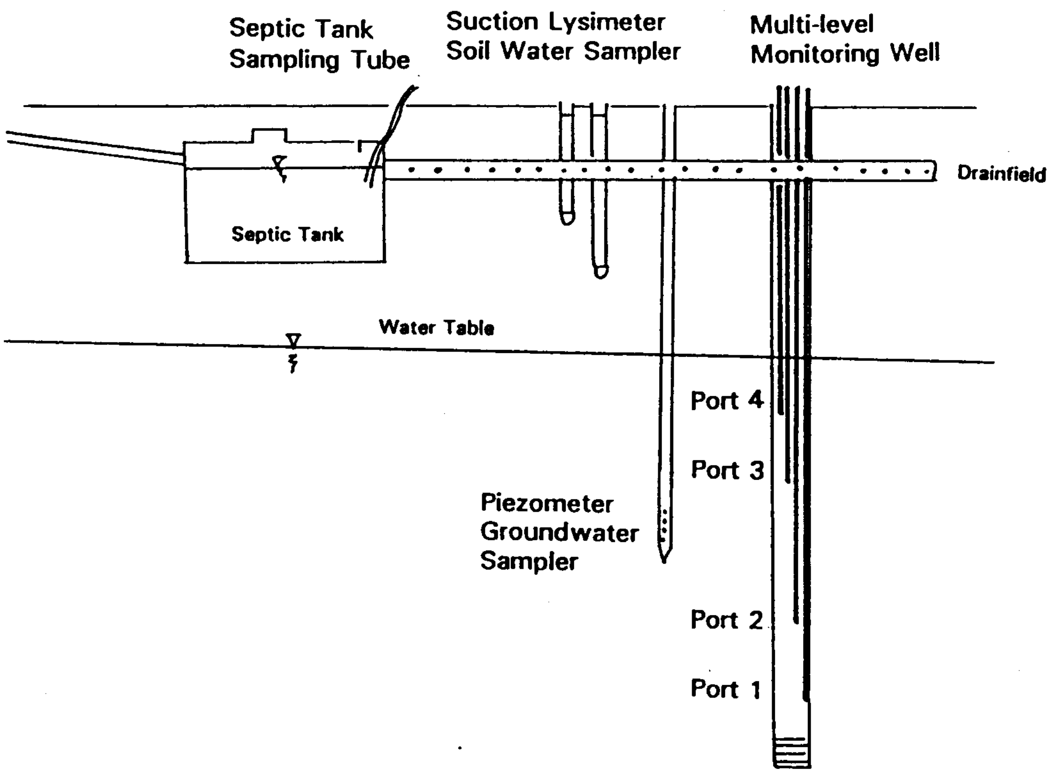


Table 9 shows the change in septic system constituents from the septic tank to the groundwater system at the North Missoula Carrying Capacity study site used by Woessner et al. (1995). This site consists of a 25 year old V-shaped drainfield installed in coarse sand and gravel. The water table is between five and eight feet below ground surface. Data in the table are for well 1M2, which was drilled directly under the active portion of the drainfield, and is a multilevel well. Port 4, which is closest to the water table, is designated as 1M24. The other ports are at successively deeper levels. The data indicates that chloride passes untreated from the septic system to groundwater. The chloride levels in the septic system effluent at this site were also higher than normal due to the disposal of water softener regeneration wastes into the septic system.

Nitrogen in the form of ammonia is oxidized rapidly to nitrate in the unsaturated (vadose) zone. The levels of total nitrogen measured in the soil samplers (lysimeters) are lower than expected and the data indicates an overall reduction of 78% in nitrate concentration between the septic tank and groundwater. This does not necessarily indicate a 78% removal rate for total nitrogen however, due to the fact that the levels of nitrate measured in groundwater are reduced by dilution. It is also possible that laboratory analysis for nitrate was inhibited by the high chloride level, and the reported values are lower than the actual levels (Woessner et al., 1995). Fecal coliform bacteria were consistently found in the two shallowest ports of the multilevel groundwater monitoring well. Woessner et al. (1995) concluded that the elevated levels of nitrate, ortho-phosphate and chloride, along with the reduced levels of dissolved oxygen and presence of fecal coliform bacteria in the groundwater, indicated that waste water was rapidly infiltrating to the groundwater system.

TABLE 9
Septic system treatment data, Missoula North Site

SAMPLE POINT	DISS. OXYGEN	AMMONIA	NITRATE	CHLORIDE	ORTHO-PHOSP	FECAL COLIFORM COL/100ML
TANK	0.5	26.4	ND	413.3	3.1	TNTC
SOIL-L1	NA	0.5	1.0	668	4.7	NA
SOIL,L2	NA	0.1	2.8	726	ND	NA
1M24	3.8	ND	3.8	436.7	0.7	21
1M23	3.5	0.3	1.0	46.1	ND	48
1M22	4.1	ND	0.7	22.6	ND	ND
1M21	5.0	ND	0.9	5.2	ND	ND

ND=none detected, NA=none applicable, TNTC=too numerous to count
Source: Woessner et al. (1995), from Missoula North Site

4.0 STUDY METHODS

This study used existing data on developed properties, septic systems, soils, hydrogeology, public and private water supply wells, along with sampling of private wells and monitoring wells.
Groundwater samples were collected from private wells and monitoring wells within and around high density unsewered areas to document current groundwater quality. The most recent nitrate data available from public water supply wells within the study area were obtained from the State Water Quality Division. Groundwater sampling data from previous studies were reviewed and compared to sampling results from this study to determine if nitrate-N levels in unsewered areas showed any trends.

Related information was also evaluated to rank the relative potential for septic systems within the unsewered areas to cause degradation of groundwater and pose public health threats. This information included septic system densities, types of septic systems, percentage of replacement septic systems, depth to groundwater, hydraulic conductivity, groundwater flow direction, locations of wells, cumulative impacts (loading) to groundwater, soils, geology, and land use. The hydrogeologic data, excluding groundwater flow direction, was evaluated using a methodology developed by the United States Environmental

Protection Agency (EPA) called DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings (EPA, 1987). The following subsections describe the methods used to delineate study areas, establish a background nitrate level, utilize existing data bases, develop a project data base, select sampling locations, collect groundwater samples and rank aquifer sensitivity using the EPA DRASTIC method.

4.1 DELINEATION OF STUDY AREAS

The following criteria were used to evaluate unsewered areas and select high density unsewered areas for study:

1. Located within the boundaries of the Water Quality District
2. Density of septic systems greater than 1 per 4 acres
3. Extension of public sewer possible within next 15 years

The initial area of review for the project was the area contained within the boundaries of the Missoula Valley Water Quality District (District). The boundaries of the District are shown on the attached maps included in this report. The District covers approximately 206 square miles.

Eight areas were selected for evaluation based on the above criteria. The areas selected for study were East Missoula, the East Reserve Street area, Lolo, the Mullan Road area, the lower and middle Rattlesnake Valley, the West Reserve Street area, West Riverside and Westview Park.

Pattee Canyon, O'Brien Creek, Miller Creek, Grant Creek, the Big Flat area, the Frenchtown area, the Wye area and the Linda Vista subdivisions were evaluated but not selected for detailed study. However, water quality sampling was conducted in these areas.

The Miller Creek Valley was not included due to the low density of development in the valley. Based on the septic system density mapping (see Attachment A) none of the quarter sections in the Miller Creek Valley had septic system densities greater than 1 septic system per 4 acres. A total of 88 unsewered properties were identified in the valley, and 68 of those were in the upper portion of the Valley. One domestic well in the most highly developed area of the upper Miller Creek Valley was sampled during the project and showed low levels of nitrate-N.

The Grant Creek Valley was not selected due to the fact that the lower half is currently served by public sewer and the density of septic systems in the upper portion of the valley was not above 1 septic system per 4 acres. The only exception is the Keegen Trail area, in the northwest quarter of section 21, which had a total of 43 septic systems (3.8 acres per system). Three private wells in the upper Grant Creek Valley were sampled during the project. None of these wells showed bacterial contamination and nitrate-N levels were low. Data from two public water supply wells in the valley were also evaluated and showed low levels of nitrate-N.

The Big Flat area was not included due to the lower density of homes in this area, and the low probability of sewer service being extended into the area within the next 15 years. Data from one public water supply well was obtained from this area, and one private well was sampled during the project. Both wells showed nitrate-N levels above background. The private well had an average nitrate-N level above 0.75 mg/l.

The Frenchtown area was not included because it was considered unlikely that public sewer would be available in the next 15 years, and the area is being studied as part of Phase II of the Missoula County Carrying Capacity Study. The Environmental Health Division of the Health Department has also collected recent bacteria data in the Frenchtown area as a separate project.

The Linda Vista area was not included because public sewer service is currently being extended into the area. There has also been a significant amount of data collected in the area by the Missoula City-County Health Department and local Hydrologist Howard Newman. The WQD is currently collecting groundwater samples from 11 domestic wells in Linda Vista on a quarterly basis. The wells selected have all historically exceeded the drinking water standard for nitrate of 10 mg/l. This sampling will provide water quality data before and after connection of a high density subdivision to public sewer.

4.2 ESTABLISHMENT OF BACKGROUND NITRATE LEVEL

In order to evaluate current groundwater impacts from septic systems, a background nitrate-N level of 0.1 mg/l was used for this study. Nitrate-N levels above 0.1 mg/l were interpreted to be from septic system impacts. This background level is the same as the background level established by Juday and Keller (1978) for the Missoula Valley Water Study.

Septic systems are a known source of nitrate contamination in groundwater (Canter and Knox, 1985). It is usually assumed that elevated nitrate levels in groundwater under unsewered areas are caused by septic systems, unless agricultural sources or other known sources of nitrate are present. Other sources of nitrate that may enter groundwater include nitrate in precipitation, urban stormwater, surface water recharge, leaky sewer mains, agricultural sources and residential lawn fertilizer. These other potential sources were evaluated during this study, and are not believed to contribute significant quantities of nitrate to groundwater, based on the following factors:

Nitrate from Recharge of Precipitation;
Local levels of nitrate in precipitation range from 0.02 to 0.05 mg/l (Juday, personal communication). Potential annual evapotranspiration (evaporation and plant uptake) rates in the Missoula Valley exceed annual precipitation rates. This indicates that recharge to groundwater from precipitation is negligible based on annual averages, but it is possible some precipitation

recharges groundwater during the winter and spring.

Soil profiles in Lake Missoula silts and alluvial valley fill show development of calcium carbonate horizons, indicating that the soils are not regularly flushed by precipitation. Based on the relatively low levels of nitrate in precipitation and the evidence that very little precipitation recharges the aquifer, this source was not considered a major contributor of nitrate to groundwater in the study areas.

Nitrate from Recharge of Stormwater;
As part of a study of water quality impacts of liquid deicers, the Water Quality District collected 17 grab samples of stormwater runoff in Missoula between February 14, 1994 and March, 1995. The average nitrate-N concentration was 0.29 mg/l, which is above the established background of 0.10 mg/l. Stormwater from the downtown area, portions of the University area, Brooks Street (west of Russell), and Reserve Street between Brooks and the Clark Fork River is discharged to surface water. The quantity of stormwater that recharges the aquifer by entering stormdrain sumps is unknown. However, since the levels of nitrate are low, stormwater is not believed to be a significant source of nitrate to the aquifer.

Nitrate from Recharge of Surface Water;
Extensive data have been collected on the levels of nitrate in the Clark Fork River, which is the primary source of recharge to the aquifer (Clark, 1986). In 1988, nitrate levels in the Clark Fork below Milltown Dam and above the waste water treatment plant averaged 0.012 mg/l and 0.017 mg/l respectively (Ingman and Kerr, 1990). These levels are below the established background of 0.1 mg/l, so recharge from surface water was also not considered a significant source of nitrate to groundwater in the study area.

Nitrate from Minerals and Agricultural Activities;
There are no known mineral sources of nitrate in the Missoula Valley Aquifer. The hardest potential source to quantify is the potential input of nitrate from agricultural activities and application of chemical fertilizers. There is very little livestock grazing and farming within the areas evaluated, with the exception of limited livestock in the West Reserve Street area. Impacts from livestock in the West Reserve Street area are unknown, but assumed to be small, due to the fact that the amount of livestock is limited and recharge from precipitation is limited.

Nitrate from Lawn Fertilizers;
Application of lawn fertilizer could contribute nitrate to groundwater if lawns are heavily watered. Irrigation rates would have to exceed evapotranspiration rates, and plant uptake of nitrogen would have to be less than the rate of fertilizer application. No local research has been done to evaluate this potential source of nitrate. Further research to evaluate the potential impacts from fertilizer application is needed.

4.3 USE OF EXISTING DATA BASES

Existing data bases maintained by other agencies were used whenever possible for this study. These data bases were obtained for information on septic systems, depth to groundwater, hydraulic conductivity, hydraulic gradient, soils, public sewer connection records and records of improved properties. Table 10 shows the agencies contacted and the data bases obtained from each agency. Several data bases from Missoula County Information Services were used to help determine the number of septic systems within the District and within the boundaries of the unsewered areas.
Because no single data base exists that contains the number of septic systems in the study area, several data bases containing related information were combined to estimate the number of units using septic systems. A unit is defined as a single commercial property, a single family residence, an apartment in a multifamily development or a mobile home. In general, information on the numbers of improved properties, mobil homes, multi-family developments and commercial properties were combined with data bases containing information on public sewer connection records.

Data bases from Missoula County Information Services on County sewer Rural Special Improvement District (RSID) assessments and public sewer connection records obtained from the City of Missoula Public Works Department were used to determine the number of units on public sewer. These records were cross referenced with information on the number of improved properties in the study area, obtained from Missoula County Information Services. The units connected to pubic sewer were subtracted from the total number of units to determine the number of units on septic systems.

Information on the types of septic systems in unsewered areas was obtained from SEWPER, a data base maintained by the Environmental Health Division of the Missoula City-County Health Department. The locations of private wells, and the depth to groundwater were obtained from a data base of drillers logs maintained by the Montana Bureau of Mines and Geology. The locations of public water supplies, and water quality data for public water supplies was obtained from the Montana Department of Environmental Quality, Water Quality Bureau. Data on hydraulic conductivity and hydraulic gradient values compiled by Land & Water Consulting Inc., for the Missoula County Carrying Capacity study, were also obtained.

Table 10
Data obtained from other sources

AGENCY/SOURCE	DATA OBTAINED
Msla City-County Health Dept.	Septic Permits (SEWPER) Groundwater Monitoring Records
Land & Water Consulting Inc.	Hydraulic Conductivity, Hydraulic Gradient
City of Missoula Public Works Engineering Division	Sewer Connection Database
Missoula County Information Services	County Sewer RSID Assessment Records (Lolo & Elma), Records of Mobile Homes in County, Records of Improved Properties with Classification Codes
Montana Department of Revenue	Records of Multifamily Dwellings (CAMAS database)
DEQ Water Quality Bureau	Public Water Supply Data
USDA Soil Conservation Sev.	Missoula Co. Soil Survey
MT Bureau of Mines and Geol.	Water Well Records, Drill Logs

4.4 DEVELOPMENT OF PROJECT DATABASES

The locations of sampling sites (private wells and monitoring wells) were initially determined by address matching. The locations were later refined by researching legal descriptions based on Missoula County Assessor's records. The sampling locations, and sampling results for nitrate and bacteria were entered into a database compatible with geographical information system (GIS) software, using Dbase IV™. The water quality sampling data and all data for septic systems, geology, soils, well locations, and other information were input into GIS using PC ArcInfo/ArcCad™ software.

4.5 COMMERCIAL LAND USE

Since disposal of commercial or industrial wastewater into septic systems can contribute other contaminants to groundwater, unsewered areas with commercial businesses were considered to pose a higher threat to groundwater than wholly residential areas. Commercial land use in each area was evaluated based on assessor's records for commercial properties. A commercial property was considered to be equal to one unit. The percentage of commercial units in each area was determined by comparing the number of commercial units to the total number of units in the area. The eight unsewered areas were ranked in order, based on the percentage of commercial properties.

4.6 SEPTIC SYSTEM DENSITY MAPPING

According to the U.S. Environmental Protection Agency (EPA), the most important factor influencing groundwater contamination from septic systems is the density of septic systems (EPA, 1977, in Yates, 1985). Data on the density of septic systems within the boundaries of the District were obtained by combining data base information from State Department of Revenue assessment records of real property and mobile homes with County sewer RSID assessment records and City of Missoula sewer connection records. The Department of Revenue records were obtained to provide a listing of all real property and mobile homes. The available real property database was from a file that reflected parcel data as of January 1, 1995. Mobile home counts were obtained for Water Quality District fee billing records, and reflect mobile home numbers as of March, 1995. County sewer RSID assessment records and City sewer connection records were also from files obtained in March 1995.

These data bases were combined to create a GIS map layer showing the calculated total number of residential and commercial units in each quarter section, and the number of units on individual sewer systems within each quarter section. This map is included as Attachment A. Locational information corresponding to the Public Land Survey System (PLSS), delineated by township, range and section, for each parcel was determined by using a geocode number included in the records obtained from the State Department of Revenue. Through the use of this coding system it was possible to summarize tax parcel and mobile home sewer information for each quarter-section. The eight unsewered areas were ranked in order, based on the density of unsewered units.

4.7 CUMULATIVE IMPACTS/NITROGEN LOADING

Based on the total number of septic systems in each area, calculations were made to determine the total loading of sewage and nitrogen to the subsurface in each unsewered area. To be consistent with values used in the Missoula County Carrying Capacity study and the non-degradation rules established by the State Water Quality Division, total nitrogen loading was calculated using an average concentration of 50 mg/l in septic system effluent. The volume of sewage discharged to groundwater in each area was calculated by multiplying the number of unsewered units in each area by an average discharge volume of 200 gallons/day.

These calculations were used to determine relative, cumulative impacts to groundwater and surface water from each unsewered area. Total nitrogen loading was calculated to evaluate the relative impacts of each area to surface water, based on the rational that the majority of the total nitrogen discharged from a septic system is converted to nitrate, and nitrate that reaches groundwater is eventually discharged to the Clark Fork or Bitterroot Rivers. For comparison, calculations were also made of total nitrogen loading to the Clark Fork River from the Missoula Waste Water Treatment Facility. The results for cumulative impacts and nitrate loading are presented in Section 5.3.

4.8 DETERMINATION OF SEPTIC SYSTEM TYPES

The percentage of seepage pits and cesspools in each area was determined by comparing the number of permitted seepage pits in each area to the total number of permitted septic systems in each area. These records were obtained from the Missoula City-County Health Department's septic system permit database (SEWPER), which contains records of all known septic system permits issued since 1967.

Because drainfields were not in use prior to the requirement for septic system installation permits, all known drainfields are counted in the data base. The only exception would be drainfields that were installed illegally, after 1967, without a permit. The calculated percentage of seepage pits in older areas is probably lower than the actual percentage, since all older systems not included in the SEWPER database are seepage pits or cesspools. Based on the percentage of seepage pits in each area, an ordinal ranking score between one and eight was assigned to each area. The area with the highest percentage of seepage pits was assigned the highest ranking value of eight. The results are presented in Section 5.4.

4.9 PERCENTAGE OF SEPTIC SYSTEMS REPLACED SINCE 1967

To evaluate relative septic system failure rates, the percentage of replacement septic systems in each area was determined. This was done by comparing the total number of living units on septic systems within each area to the number of replacement septic system permits issued by the Missoula City-County Health Department since 1967. Because permits to replace septic systems were not required prior to 1967, no records of earlier replacements area available. In general, areas with older systems or tight soils tend to have a higher percentage of replacements.

An ordinal ranking score between one and eight was assigned to the eight areas, with the highest ranking value assigned to the area with the highest percentage of replacement permits. The results for this ranking are presented in Section 5.5.

4.10 GROUNDWATER QUALITY SAMPLING

Current groundwater quality was evaluated in the unsewered areas by collecting nitrate-N and coliform bacteria samples from private wells, collecting nitrate-N samples from monitoring wells, and obtaining the most recent nitrate-N data from public water supply wells. The most recent nitrate-N data available from public water supplies were obtained from the State Water Quality Division. Records were obtained for 216 public water supply wells. This number includes 34 wells operated by Mountain Water Company, which serve most of the Missoula urban area. A total of 153 private wells were sampled for nitrate-N and coliform bacteria. Most of these wells were sampled quarterly for four quarters, starting in the Summer of 1994. Some private wells were added to the sampling network during the study and were not sampled during all four quarters. During the last quarter of sampling, 23 monitoring wells established for the District's monitoring well network were also sampled. The monitoring wells sampled include seven wells installed by The University of Montana for various past studies, 12 wells installed in the Winter of 1995 by the District and four wells installed by ARCO to study the hydrogeology between Milltown Dam and the mouth of Hellgate Canyon.

The areas were not ranked based on bacterial results due to a lack of sufficient data to provide a relative ranking. An average nitrate value was calculated for each area by averaging the values for all available nitrate-N sampling results. The areas were assigned an ordinal ranking value between one and eight, with the area having the highest average nitrate value being assigned a ranking value of eight. The results for ranking based on average nitrate-N concentrations in groundwater are presented in Section 5.6. Nitrate and bacterial sampling results are also summarized on maps included in this report as Attachments B and C. Limited sampling of private wells and monitoring wells for volatile organic compounds was also completed during the first quarter of sampling in Summer, 1994 and the final round of sampling in Spring, 1995.

4.10.1 SELECTION OF SAMPLING LOCATIONS

Three methods were used to obtain access to private wells for sampling purposes. First, staff selected preferred well locations from the Montana Department of Natural Resources (DNRC) data base and contacted the owners concerning use of their well. This method was generally unsuccessful. Second, staff contacted well owners who had granted permission for use of their wells in previous studies. Most of these well owners agreed to participate. Use of these wells allowed for comparison of historical data with data collected during the project. Finally, the Missoulian newspaper ran an article in which the Water Quality District requested volunteers who were willing to allow use of their private wells for the study. This method produced over 100 participants, and resulted in a fairly random selection of sampling locations. Approximately 15 additional wells were added during the study as a result of meeting with neighborhood groups from the Rattlesnake Valley and the Reserve Street area.

4.10.2 EVALUATION OF NITRATE TRENDS

Historical data collected by Juday and Keller (1978), and Woessner (1988) were compared with data collected by the District in unsewered areas for this study. An effort was made to obtain access to wells which had been sampled for these studies. Access was obtained for 30 of the wells used by Juday and Keller, and 10 wells used by Woessner. The nitrate-N data for wells that had been sampled during previous studies were tabulated and compared with nitrate-N results obtained during this study, to determine if any of the wells showed nitrate trends. Historical data from McMurtrey et al. (1965) was also reviewed, but data form only a few wells in unsewered areas were included in this report, and the exact well locations are unknown.

4.10.3 NITRATE-NITROGEN SAMPLING

Groundwater samples were collected for nitrate-N analysis from private wells and monitoring wells in the study area. Samples were collected in clean 250 milliliter (ml) polyethylene bottles. Most of the private wells were sampled quarterly, but some were added during the project, and some wells were not accessible on a quarterly basis. The bottles were cleaned prior to sampling by washing with Alconox™ detergent, triple rinsing with tap water and doing a final rinse with deionized water. To verify that the cleaning procedures were effective, a bottle blank was submitted to the laboratory for each sampling round. The bottle blanks were prepared by randomly selecting a bottle after it had been cleaned, and filling it with deionized water.

In the field, the bottles were rinsed three times with water from the sampling tap prior to collection of the sample. Outside taps were used whenever possible to minimize disturbance of the residents. The sampling taps were flushed for 10 to 15 minutes to purge the wells prior to sample collection. A water hose was connected to the tap during flushing to discharge the water away from foundations or low areas where water would pond.

Dr. Juday at The University of Montana Chemistry Department analyzed the water samples for nitrate-N. To verify the quality of Dr. Juday's results, split samples were taken and submitted to the Montana Department of Environmental Quality Chemistry Laboratory Bureau in Helena for analysis. At the request of Dr. Juday, nitrate-N samples were transported to the laboratory each day after sampling, and were not preserved with sulphuric acid. Samples submitted to the Chemistry Laboratory Bureau were preserved with sulphuric acid prior to shipping to the laboratory.

Duplicate samples and standards were also sent to Dr. Juday to verify sample quality. The results of these quality control measures are discussed in section 5. Some repeat sampling was also done to see how nitrate levels varied over short periods of time.

4.10.4 BACTERIA SAMPLING

Groundwater samples were collected for coliform bacteria analysis from private wells. The number of wells sampled varied slightly each quarter. Monitoring wells sampled for nitrate-N during the study were not sampled for bacteria due to well construction and the sampling methods used. None of the monitoring wells had sealed caps to keep insects and debris from entering the wells. The use of portable pumps and hand bailers also restricted sampling since the wells could not be purged and sampled using sterile techniques. Bacteria samples were collected from domestic wells at the same time nitrate-N samples were collected. Samples were collected in sterile, 100 ml, plastic (nalgene) bottles prepared by the laboratory. The samples were preserved with sodium thiosulfate, refrigerated immediately after collection, and transported to the laboratory at the end of each sampling day. Bacteria samples were analyzed within 24 hours at the Missoula City-County Health Department using the total coliform membrane filter test, following Standard Methods for the Examination of Water and Wastewater. The Missoula City-County Health Department Laboratory is certified and inspected by the Montana Department of Public Health and Human Services (DPHHS).

4.10.5 VOC SAMPLING

Limited sampling of private wells and monitoring wells was completed as part of this study to determine if unsewered areas are a source of volatile organic compounds (VOCs). Groundwater samples were collected from selected wells in unsewered areas during Summer, 1994. After the District's monitoring well network was established in Spring, 1995, a second round of VOC samples was collected. VOCs are found in solvents, paints, cleaning compounds, agricultural chemicals, and fuels. Several of these compounds have been detected in the Missoula Aquifer. The most common VOC found in the Missoula aquifer is tetrachloroethylene (PERC). Limited sampling completed as part of Phase II of the Carrying Capacity study indicated that septic tank effluent may be a possible source of 1,2-dibromo-3-chloropropane (DBCP) and tetrachloroethylene (Woessner et. al, 1995).

Precleaned 40 ml glass vials with silicone septum caps were used for collection of VOC samples. The vials were precleaned by the distributor and were provided by the laboratory that performed the analysis. VOC samples were collected from each sampling site at the same time that nitrate and bacteria samples were collected. The samples were preserved with hydrochloric acid, refrigerated immediately after collection, and shipped to the laboratory for analysis.

Samples were analyzed for VOCs using EPA Method 524.2. For the first round of sampling all of the samples except for one split sample were sent to SVL Analytical Laboratories in Kellogg, Idaho. A split sample was sent to Energy Laboratories in Billings, Montana. VOC samples collected for the second round of sampling were sent to National Testing Laboratories in Ohio.

Standard procedures were followed for collection of VOC samples. For quality control and quality assurance, trip blanks and confirmation samples were also submitted to the laboratory for analysis. One trip blank was submitted to the laboratory for analysis for each sampling round. The trip blank consisted of a sample bottle prefilled with clean water at the laboratory. The sample accompanied the sample bottles provided by the lab during all sampling, storing and shipping procedures. The purpose of the trip blank is to reveal any cross-contamination of the samples during collection, transport and shipping.

4.11 REGIONAL GROUNDWATER FLOW DIRECTION

To determine potential down gradient well users that may be impacted by septic systems in high density areas, regional groundwater flow directions were determined for each unsewered area and compared with data on public and private well locations. While this factor was not ranked directly, the ranking assigned for cumulative impacts and nitrate loading can be evaluated in the context of groundwater flow patterns.

Potentiometric surface (water table contour) maps from existing hydrogeologic reports were used, if available, to determine groundwater flow directions around unsewered areas. The Rattlesnake Valley and the Lolo area were the only unsewered areas not covered by existing hydrogeology reports. In these two areas topography and geology were evaluated to determine groundwater flow directions. Hydrogeologic reports by Perry (1988), Pottinger (1988), Miller (1990), Armstrong (1991), Smith (1992) and Land & Water Consulting Inc. (1994) were used to determine regional groundwater flow directions in unsewered areas.

4.12 LOCATIONS OF PUBLIC AND PRIVATE WELLS

Locations of public water supply wells were determined based on locational data provided by the State Water Quality Division. The Water Quality Division recently surveyed all the public water supply well locations in the Missoula area using a global positioning system (GPS) receiver. Using the GPS survey data, the well locations were mapped with GIS software.

Data on the location and number of private wells in the study area were obtained from a data base maintained by the Montana Bureau of Mines and Geology. The locational information is based on drillers logs filed with the Bureau. This was also mapped using GIS software. Once the private well locations were mapped, the number of private wells in each unsewered area was calculated using GIS software. The unsewered areas were then ranked in order, based on the density of water supply wells in each area.

4.13 EVALUATION OF HYDROGEOLOGIC DATA USING EPA DRASTIC METHOD

The Environmental Protection Agency (EPA) DRASTIC method was used to evaluate hydrogeological properties of unsewered areas (EPA, 1987). The DRASTIC method was developed to provide a standardized system for evaluating groundwater pollution potential based on available hydrogeologic data. DRASTIC is an acronym for the seven hydrogeologic properties that the model uses, which are as follows:

D-Depth to groundwater
R-Recharge from Precipitation (net)
A-Aquifer media

S-Soil media
T-Topography
I-Impact of the vadose zone
C-Conductivity of the aquifer (hydraulic conductivity)

The DRASTIC method was developed to assist planners, managers and administrators in the task of evaluating the relative vulnerability of areas to groundwater contamination from various sources of pollution (EPA, 1987). Use of the method provides a relative numerical rating for the areas studied. It is designed to provide a broad, general assessment of areas at least 100 acres in size to pollution potential, and is not designed to replace a detailed hydrogeologic analysis of a specific site for purposes such as siting a landfill or a septage land application site.

DRASTIC assumes pollutants are introduced at the surface and have a mobility like water (water soluble, non-reactive). This method was used by Shannon (1986) for the Missoula Valley Aquifer. The work, however, was completed prior to the availability of current Geographical Information System (GIS) computer software. For this study, a modified version of the DRASTIC method was used to obtain a relative aquifer sensitivity value for each unsewered area. Specifically, DRASTIC was redone for this study to accomplish the following objectives:

1. Develop data files for the DRASTIC factors using GIS, to allow for easy revisions of the data layers and to allow for production of DRASTIC maps at various scales.

2. Incorporate new data obtained since 1986.

3. Provide a non-biased, relative ranking system for evaluating the hydrogeologic properties of the unsewered areas.

DRASTIC uses a numerical ranking system based on weights, ranges and ratings to calculate a "DRASTIC Index" for each grid cell in the study area. For this study, quarter-quarter sections of 40 acres in size were used for evaluating the factors. Each hydrogeologic factor was evaluated by EPA and assigned a relative weight (w) based on the importance of the factor in determining the fate of a contaminant. The weights assigned to the hydrogeologic properties vary from 1 to 5, with factors given a weight of 5 being the most important. The DRASTIC weighting factors are presented in Table 11, and are constant values for the model. Each hydrogeologic factor is divided into ranges or media types, and the ranges and media types are assigned a rating (r). The ranges and ratings for some factors were modified as discussed below. Weighting factors were not modified.

The DRASTIC Index for each unsewered area was computed for each 40 acre cell within the boundaries of the area covered by the Missoula Aquifer

Protection Ordinance, using the following equation, where r=rating value and w=weighting value:

$$\textbf{Drastic Index} = D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w$$

Once DRASTIC index values were determined for all the cells in the study area, an average index value was determined for all the cells within each unsewered area using GIS software.

TABLE 11
Assigned weights for DRASTIC factors

DRASTIC Factor	Weight
Depth to Water	5
Net Recharge	4
Aquifer Media	3
Soil Media	2
Topography	1
Impact of Vadose Zone	5
Hydraulic Conductivity	3

Modifications to DRASTIC;
The following modifications were made to the original DRASTIC method for purposes of evaluating unsewered areas:

1) The ranges and ratings for depth to groundwater were modified to make the depth to water rating more sensitive at shallow depths, and to reflect the Missoula City-County Health Code requirement that seasonal high groundwater be at least six feet deep, for septic system installation. Table 12 provides the original and modified depth to groundwater ranges and ratings for comparison.

2) The original DRASTIC method uses a factor called aquifer media, which has ranges and ratings based on general geology. Sand and gravel is a single range in the original method, and assigned a rating value of eight. Since most of the areas studied are over sand and gravel aquifers, the importance of aquifer media is related to hydraulic conductivity. The coarser the aquifer media, the faster groundwater can transport contaminants. For this reason, hydraulic conductivity values obtained from Land & Water Consulting Inc. were also used to represent aquifer media values.

TABLE 12
Original and modified DRASTIC ranges and ratings for depth to groundwater*

ORIGINAL DEPTH RANGE (feet)	ORIGINAL RATING	MODIFIED DEPTH RANGE	MODIFIED RATING (feet)
0-5	10	0-6	10
5-15	9	6-12	9
15-30	7	12-20	8
30-50	5	20-30	7
50-75	3	30-40	6
75-100	2	40-50	5
+100	1	50-60	4
		60-80	3
		80-100	2
		+100	1

* Depth to groundwater weighting factor = 5

Determination of DRASTIC Values;
Numerous sources of data were used to obtain data for the DRASTIC factors. The data sources and methods used are described below, following the order of DRASTIC.

(D) Depth to Groundwater;
Depth to groundwater was determined based on data from the following sources:

1) Static water levels provided in well drillers logs, obtained from the Montana Bureau of Mines and Geology.

2) Groundwater monitoring records maintained by the Missoula City-County Health Department for subdivisions.

3) Review of potentiometric maps in hydrogeologic reports from Miller (1990), Armstrong (1991) and Smith (1992).

An average depth value for each quarter-quarter section of the study area was entered on a map, and then input into GIS.

(R) Recharge;
Net annual recharge from precipitation for the unsewered areas studied was assumed to be negligible for the reasons discussed in Section 2. A single rating value of 1 was used for net recharge from precipitation for all unsewered areas. DRASTIC assigns a rating of 1 to areas that have from 0-2 inches of net annual recharge from precipitation. The weighting factor for recharge is 4, so all unsewered areas were given an index value of 4 for recharge. In essence this removes this model parameter.

(A) Aquifer Media;
As discussed above, aquifer media were determined by matching the values used for hydraulic conductivity. A data base of hydraulic conductivity values for the study area was obtained from Land & Water Consulting Inc., located in Missoula. This data base was prepared for Phase I of the Missoula County Carrying Capacity Study.

(S) Soils;
Soils maps and text descriptions for all soils in the study area were obtained from the Missoula County Soil Survey prepared by the USDA Soil Conservation Service (SCS) office in Missoula. The soils maps consisted of aerial photographic base maps with the soils units and identification numbers mapped on the photographs. The Soil Conservation Service also provided a text file with descriptions of all the soils in the study area. This information was used to assign rating values to soil types. Data for entry into GIS was obtained from the Office of Community Development (OCD). OCD digitized the soils maps, and these files were used to input soils data into GIS for DRASTIC. The range and rating values used for soils were based on the soil type description, permeability, moisture holding capacity, drainage characteristics and limitations for septic systems provided by SCS in the text descriptions for each soil type. Table 13 shows the soil textures present in the study area and the ratings assigned.

TABLE 13
Ranges and Ratings for Soils using DRASTIC

SOIL TEXTURE	RATING
Riverwash/gravel pits	10
Gravelly Loam	7-9
Sandy Loam	6-8
Loam	5-7
Silty Loam	4
Clay Loam	3

(T) Topography;
The unsewered areas are in relatively flat topography. DRASTIC assigns higher values to flat ground than to sloping ground. The highest rating assigned is 10 for topography with 0-2% slope. Data obtained from Land & Water Consulting Inc. for hydraulic gradient, based on topographic slope, were used to input topographic data.

(I) Impact of the Vadose Zone;
The properties of the unsaturated sediments above the water table (vadose zone) were based on the surface geology. Surface geology by McMurtry et al. (1965) was transferred to United States Geological Survey (USGS) 7.5 minute topographic maps and then digitized for entry into GIS. Table 14 shows the surface geology units mapped for the study area and the DRASTIC rating values assigned to each map unit.

TABLE 14
DRASTIC rating values for surface geology (vadose zone)

SURFACE GEOLOGY UNIT	RATING
Recent Alluvial Deposits	9
Pleistocene Alluvial Deposits	8
Glacial Lake Missoula Deposits	2
Tertiary Sands and Gravels	5
Tertiary Deposits (finer)	3
Basement Rock (pre-Cambrian)	10

(C) Hydraulic Conductivity;
A data base of hydraulic conductivity values for the study area, prepared by Land & Water Consulting Inc, was obtained and entered directly into GIS for the DRASTIC analysis. Ranges and rating values for hydraulic conductivity are presented in Table 15.

TABLE 15
Hydraulic Conductivity Ranges and Ratings for DRASTIC

RANGE (GPD/FT)	RATING
1-100	1
100-300	2
300-700	4
700-1000	6
1000-2000	8
>2000	10

After the DRASTIC input data were evaluated, an average DRASTIC value for each area was calculated using GIS. The unsewered areas were then ranked in order, based on the average DRASTIC value (see Table 29).

5.0 RESULTS

This section presents an overall summary of the results of the study. The data generated and the ranking values assigned for the factors evaluated are presented. The results for final ranking of the unsewered areas are presented in section 6. An ordinal ranking system was used to evaluate the various parameters. This method ranks the eight areas from highest to lowest for each factor being considered, and assigns a value of eight to the area that was least favorable for the factor. For example the unsewered area with the highest density of septic systems was assigned a value of eight for septic system density.

5.1 PERCENTAGE OF COMMERCIAL UNITS

For the percentage of commercial units, unsewered areas were assigned ranking values between one and eight, using an ordinal scale. The area with the highest percentage of commercial units was assigned a ranking value of eight. The number of commercial units was determined based on assessor's records obtained from Missoula County Information Services. The records were used to determine the total number of commercial and residential units. The number of commercial units in each area, the percent of commercial units, and the final ranking value assigned to each area for percentage of commercial units is presented in Table 16.

TABLE 16
Percentage of commercial units in unsewered areas

AREA	TOTAL UNITS	COMM. UNITS	% COMM. UNITS	RANKING VALUE
East Msla.	766	25	3.2	7
E. Reserve St.	3041	211	6.9	8
Lolo	456	13	2.9	5
Mullan Road	1017	14	1.4	4
Rattlesnake	1456	7	0.5	2
W. Reserve St.	1976	19	1.0	3
W. Riverside	570	17	3.0	6
Westview Park	364	1	0.3	1

The East Reserve Street area and East Missoula were assigned the highest ranking values. The East Reserve Street area had by far the most commercial properties in both total number and on a percentage basis. The records indicate that Lolo only has 13 commercial units, which appears to be lower than the actual number. This is due to the fact that the Lolo area evaluated for this study did not include the main part of town, where the Rural Special Improvement District (RSID) 901 sewer service area is located. The assessor's records also indicate that there are seven commercial properties in the Rattlesnake Valley. The actual number of commercial properties in the Rattlesnake is probably lower.

In addition to the fact that the East Reserve Street area has the highest total number and the highest percentage of commercial units on septic systems, it is also an area of documented problems related to commercial development on septic systems. The Water Quality District has documentation of three businesses that have discharged chemical waste into seepage pit systems in the East Reserve Street area, causing contamination. Two of these businesses are now listed State Superfund sites. The two Superfund sites consist of an engine rebuilder that discharged solvents, oils and heavy metals into a septic system, and a chrome plating operation that discharged plating solutions to a septic system. A third site was discovered during this study, and is currently being investigated by the Montana Department of Environmental Quality Solid and Hazardous Waste Bureau. This business was discharging wastewater from furniture refinishing into a septic system. The wastewater contained methylene chloride.

5.2 SEPTIC SYSTEM DENSITY MAPPING

Trends in Sewer Connections;
The results of the septic system density mapping are presented on Attachment A. The map shows the total number of residential and commercial units and the number of units on septic systems for each quarter section in the Water Quality District. The boundaries of each unsewered area are also shown on the map, along with the boundary of the Water Quality District.

Locational accuracy is good for parcels in most areas, and is based on geocoding using the Public Land Survey System (PLSS). There are problems in some areas, including East Missoula and Westview Park. For example, Attachment A shows that one of the southern quarter sections in East Missoula does not show any development, even though development exists. Parcels in this area were geocoded into one of the quarter sections to the north. All the units in Westview Park were geocoded into the same quarter section, even though the area overlaps several quarter sections. These errors were not considered important however, because the overall density was still well represented.

Septic system density was determined based on the total number of living units rather than the number of parcels, to account for multifamily dwellings and mobile home parks. Table 17 is a summary of the total number of improved parcels and units within the Water Quality District, and the number of living units connected to public sewer verses septic systems. A unit represents an improved commercial parcel, an improved single family residential parcel, an apartment within a multifamily development or a single mobile home.

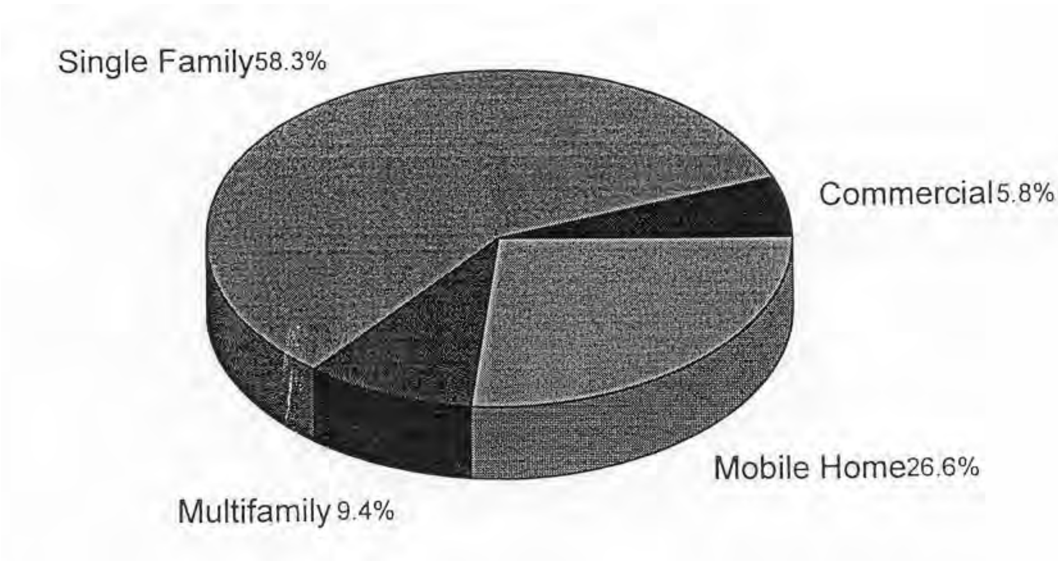
TABLE 17
Sewer status of improved parcels and living units in WQD

PROPERTY TYPE	NUMBER OF PARCELS	NUMBER OF UNITS	UNITS ON SEWER	UNITS ON SEPTIC
Commercial	1,798	1,798	1,123 (63%)	675(37%)
Residential	17,854	17,854	11,015(62%)	6,839(38%)
Multifamily	1,374	6,557	5,455 (83%)	1,102(17%)
Mobile Homes	1,380	4,219	1,096 (26%)	3,123(74%)
TOTALS	22,406	30,428	18,689 (61%)	11,739(39%)

The results show that for single family residential units and commercial units within the District, approximately 61% are connected to public sewer and 39% are use septic systems. Most multifamily units are served by public sewer (83%), while most mobile homes are served by septic systems (74%). Figure

9 shows the distribution of unsewered units within the District.

FIGURE 9
Categories of septic systems in Water Quality District



The information collected to evaluate septic system density was also used to evaluate trends in connections to public sewer verses connection to new septic systems. Table 18 shows the number of connections to public sewer and the number of septic system permits issued by the Health Department between 1990 and 1995. Figure 10 presents this data in the form of a bar graph for comparison.

TABLE 18
Public sewer connections and septic system permits between 1990 and 1995

YEAR	PUBLIC SEWER CONNECTIONS	SEPTIC SYSTEMS IN DISTRICT	SEPTIC SYSTEMS IN COUNTY*
1990	191	106	219
1991	545	157	293
1992	1,063	297	493
1993	353	226	425
1994	400	235	478
1995	476	160	315
TOTAL	3,028	1,181	2,223

* Includes septic system permits in District

The records show that for the last five years the number of new connections to public sewer has outpaced the number of new septic systems installed within the boundaries of the Water Quality District by 61%. The total number of septic systems installed in the entire County for the years 1990, 1993 and 1994 was greater than the number of new connections to public sewer. Within the County, for the six year period however, the number of new connections to public sewer surpassed the number of septic systems installed by 36%.

Septic System Densities in Unsewered Areas;
The total number of units on septic systems, the overall density of each area in units per acre, and the final septic system density ranking for each area is summarized in Table 19. The evaluation of septic system densities within each unsewered area indicates that Westview Park has the highest density of septic systems, followed by East Missoula and the East Reserve Street area. The density in the East Missoula area may be less than the density in the East Reserve Street area, due to the geocoding problems discussed previously. The Mullan Road area and Lolo had the lowest densities. The unsewered areas were ranked in order with the highest densities assigned the highest values.

Figure 10
Sewer Connections and Septic Permits, 1990-1995

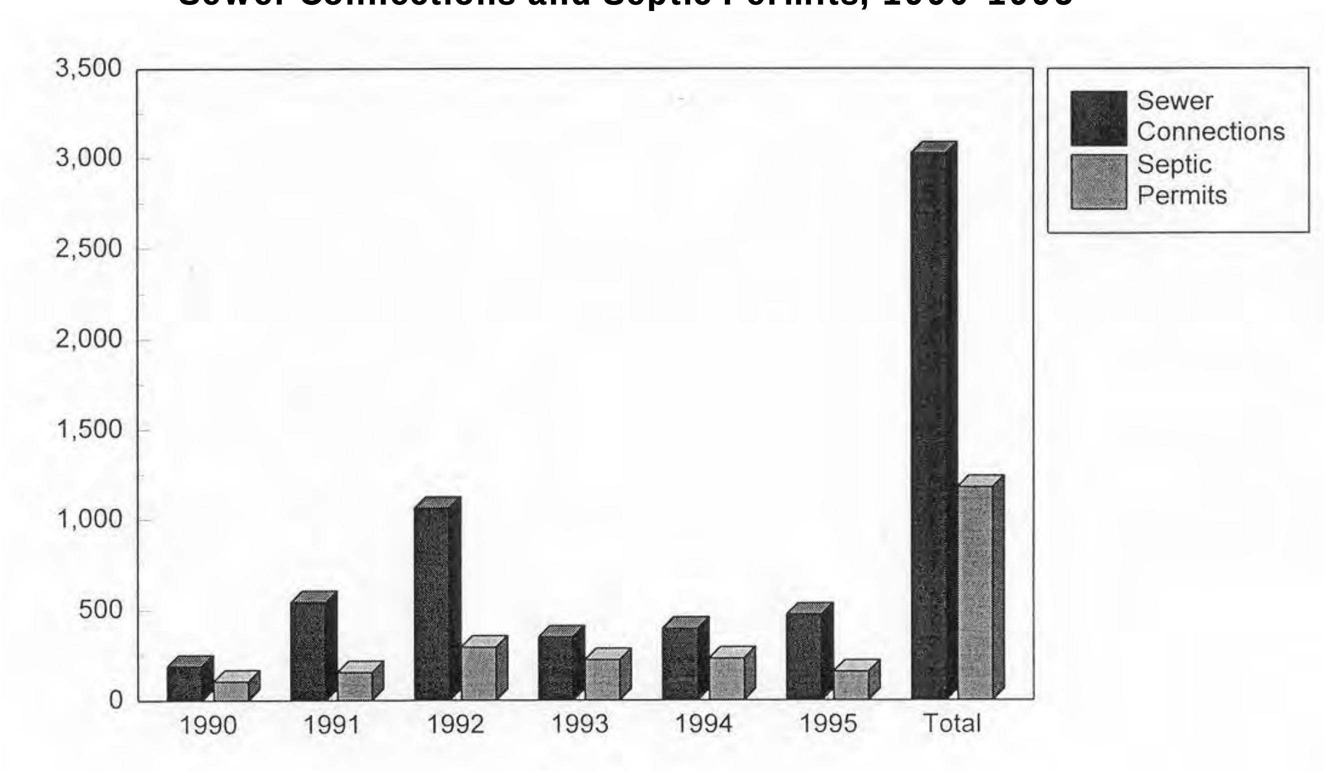


TABLE 19
Septic system densities in unsewered areas

UNSEWERED AREA	TOTAL UNITS ON SEPTIC	OVERALL DENSITY PER/ACRE	FINAL DENSITY RANKING
E. Missoula	766	1.60	7
E. Reserve St.	1977	1.54	6
Lolo	419	0.33	2
Mullan Road	627	0.23	1
Rattlesnake	825	0.57	3
W. Reserve St.	1883	0.62	4
W. Riverside	570	0.89	5
Westview Park	364	2.28	8

There are a total of 7,431 unsewered units within the eight unsewered areas evaluated. Of these, 52% are in the East and West Reserve Street areas. The East Reserve Street area contains 27% of all the unsewered units within the eight areas studied, and also contains the second highest density quarter section in the District. The quarter section located just north of South Avenue contains 540 unsewered units. The highest density unsewered quarter section is located in East Missoula, and contains 542 unsewered units, which is 7.3% of the total.

Septic system densities in sewered areas;
The septic system densities shown on Attachment A also indicate that there are still unsewered units within sewered areas, including several schools. For example one quarter section near the University of Montana shows 73 units on septic. It is unknown weather this number is accurate, or if sewer connection records in this area have not been updated. The numbers in the California Street area do not reflect recent connections to public sewer in that area. In general, the data indicates that there are approximately 322 unsewered units in the area south of the Clark Fork River and East of the East Reserve Street area.

5.3 CUMULATIVE IMPACTS/NITROGEN LOADING

The total number of units on septic systems in each area was used to calculate the relative cumulative impacts to groundwater and surface water from each area. This method was used based on the rationale that the total volume of sewage discharged from unsewered areas is relative to the total cumulative down gradient impacts to groundwater, and that the total quantity of nitrogen discharged to groundwater from unsewered areas is relative to the quantity of nitrate that is eventually discharged back to surface waters. Regional groundwater flow directions for the unsewered areas were determined based on previous local studies discussed in Section 4.11, and are presented on Attachments B and C. The areas were not ranked directly based on regional flow directions because a method of numerical ranking for flow direction could not be determined. The information on groundwater flow direction however, is useful in evaluating results of the nitrate-N sampling and other results of the study.

For calculating the total volume of wastewater discharged daily from each unsewered area, a volume of 200 gallons/unit/day (662.4 liters/unit/day) was used. To calculate the quantity of total nitrogen discharged to groundwater from each area, an average septic system effluent concentration of 50 mg/l total nitrogen was used. The results for final ranking for cumulative impacts and nitrogen loading are presented in Table 20. Figure 11 shows the total septic loading for each area.

FIGURE 11
Sewage loading by area
(Gallons Loading/Day)

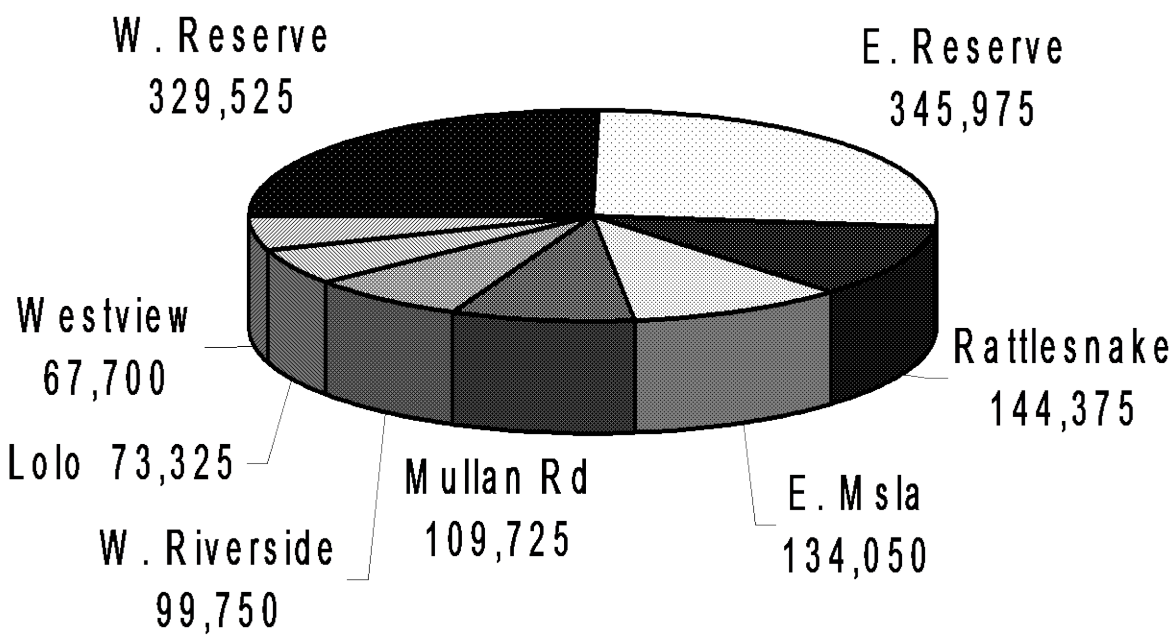


TABLE 20
Cumulative impacts and nitrogen loading in unsewered areas

AREA	TOTAL UNITS	SEWAGE LOADING*	NITROGEN LOADING lbs/day**	Final Ranking
East Missoula	766	153,200	64	5
East Reserve St.	1977	395,400	165	8
Lolo	419	83,800	35	2
Mullan Road	627	125,400	52	4
Rattlesnake	825	165,000	69	6
West Reserve St.	1883	376,600	157	7
West Riverside	570	114,000	48	3
Westview Park	364	72,800	30	1
TOTAL	7431	1,486,200	620	

*In gallons/day, based on 200 gallons/unit/day

**Based on effluent conc. equivalent to 50 mg/l total nitrogen

Total discharge of sewage to the subsurface from all eight unsewered areas is approximately 1,486,200 gallons/day, or 542 million gallons/year. Total nitrogen loading to the subsurface from all eight unsewered areas is approximately 620 pounds/day or 52,378 pounds/year. Of the total discharge from all eight areas, 52% is from the East and West Reserve Street areas. These two areas combined discharge an estimated 772,000 gallons/day of sewage, including 322 pounds/day of total nitrogen, to the subsurface.

For comparison, total sewage discharge and total nitrogen loading from the Missoula Waste Water Treatment Facility (WWTF) was also evaluated. Records of average monthly discharge and total nitrogen loading during the period from January 1993 through December, 1995 were used to calculated a weighted average discharge volume and total nitrogen loading from the WWTF. During this period the average daily discharge from the plant was 6.63 million gallons/day and the average daily loading of total nitrogen to the Clark Fork River was 1173 pounds/day. This compares with 1.48 million gallons/day and 620 pounds/day of discharge from the 7431 unsewered units in the eight unsewered areas evaluated.

If a comparison is made based on pounds of total nitrogen per million gallons of sewage discharged, the level of total nitrogen discharged from the WWTF is significantly lower than from the septic systems in the eight unsewered areas.

The WWTF discharges an estimated 177 pounds of total nitrogen per million gallons of treated effluent, while unsewered areas discharge an estimated 417 pounds of total nitrogen per million gallons of effluent.

While the treatment process at the WWTF is not generally effective for removal of nitrogen from waste water through denitrification, some denitrification probably occurs. The main reason the total nitrogen levels are lower for the treatment plant is probably that a significant amount of nitrogen as organic nitrogen and other forms is removed from the process as sludge that is made into compost. The total loading of nitrogen from septic systems also assumes that septic systems are not generally effective at removing nitrogen. Some denitrification may occur after effluent leaves a septic system, but even if 50% of the nitrogen was removed through denitrification, an estimated 208 pounds of total nitrogen per million gallons of sewage would be discharged from septic systems.

In general, this comparison indicates that connection of homes to the WWTF would probably reduce the total nitrogen loading to surface waters, based on the rationale that neither the WWTF or septic systems are very effective at denitrification, but a significant amount of the nitrogen entering the WWTF is removed in the sludge, and is not discharged to surface waters. One benefit that the WWTF has is that once sewage is collected in a central location, tertiary treatment to remove nitrogen or land application could be used to reduce impacts to surface waters.

5.4 TYPES OF SEPTIC SYSTEMS IN UNSEWERED AREAS

The final ranking for each area, based on the percentage of seepage pits and cesspools is summarized in Table 21. This information was obtained by comparing the number of permitted seepage pits to the total number of septic system permits issued since 1967. The records were obtained from the Missoula City-County Health Department's sewer permit database (see section 4.8).

To summarize records for the unsewered areas, which are delineated by quarter section, only septic system permit records that contained locational information down to the quarter section were counted. The unsewered areas were ranked and scored based on the percentage of seepage pits for the area. The sewer permit database does not contain records for most systems in the Westview Park area because most systems were installed prior to 1967. It is known that almost all of the systems are seepage pits. In most cases one seepage pit serves two mobile homes. The East Missoula and East Reserve Street areas had the highest percentage of seepage pits. The Mullan Road area, which consists of newer homes, has the lowest percentage of seepage pits.

TABLE 21
Percentage of drainfields and seepage pits in unsewered areas

AREA	TOTAL PERMITS	DRAIN FIELD	SEEP. PIT	% SEEP. PITS	FINAL RANK
East Missoula	244	59	185	76	7
East Reserve	880	242	638	73	6
Lolo	96	78	18	19	2
Mullan Road	146	122	24	16	1
Rattlesnake	608	256	352	58	4
West Reserve	987	629	358	36	3
West Riverside	105	34	71	68	5
Westview Park	14 *(182)	12	*(170)	93	8

*Estimated number of systems in parentheses, two mobile homes per system

5.5 PERCENTAGE OF SEPTIC SYSTEMS REPLACED SINCE 1967

For each unsewered area the number of replacement septic system permits issued since 1967 was compared to the total number of units on septic to estimate the percentage of septic systems replaced since 1967. The number of replacement septic permits was obtained from the Health Department SEWPER database. This method was used because the best estimate of the total number of septic systems in each area is based on the number of commercial and residential units. The only problem with this method is that multifamily dwellings and mobile homes are not accurately represented. Multifamily dwellings on septic systems usually have one large septic system. If the system is replaced, only one replacement permit shows up in the SEWPER database, even though the system serves multiple units. This may not be a significant factor since only 17% of the multifamily units are on septic. Most trailer courts also typically have several trailers connected to one septic system. For example, there is one septic system for every two mobile homes in Westview Park. This factor may not be reflected in the number of replacement permits.

The areas were ranked and scored based on the percentage of replacement systems, with the area with the highest percentage of failures assigned the highest value of eight. Table 22 shows the total number of living units on septic systems within each area, the number of replacement permits issued for each area, the percentage of replacement permits and the final ranking for percentage of replacement septic systems. The data indicates that the Rattlesnake Valley had the highest percentage of septic system failures. The

Mullan Road area, which includes a lot of new development had the lowest failure rate. This area includes systems in Lake Missoula silt deposits and systems in finer grained sands and gravels with shallow groundwater. The relatively low ranking may be due to the age of the systems, and failure rates may increase with time in the Mullan road area.

TABLE 22
Percentage of replacement septic systems in unsewered areas

AREA	TOTAL UNITS ON SEPTIC	REPLACEMENT SYSTEM PERMITS	PERCENT REPLACEMENT SYSTEMS	FINAL RANKING
East Missoula	766	67	8.8	4
East Reserve	1977	378	19.1	7
Lolo	419	25	6.0	3
Mullan Road	627	26	4.2	1
Rattlesnake	825	189	22.9	8
West Reserve	1883	312	16.6	6
West Riverside	570	57	10.0	5
Westview Park	364	17	4.7	2

5.6 CURRENT GROUNDWATER QUALITY

Current groundwater quality in and around the unsewered areas was determined by collecting quarterly groundwater samples from private wells and monitoring wells, and obtaining the most recent nitrate-N data from public water supply systems. The field sampling results for quarterly sampling of nitrate-N and bacteria from the private wells and monitoring wells is included in the report as Appendix A. Appendix B contains the most recent data collected from public water supply systems. The nitrate-N and bacteria sampling results are also summarized in map form on Attachments B and C.

The overall results of the groundwater sampling indicate that nitrate-N levels in groundwater flowing under all high density unsewered areas are above the established background of 0.1 mg/l, but well below the drinking water standard of 10 mg/l. The nitrate-N levels in the Linda Vista area remain by far the highest, and some wells in this area still exceed the drinking water standard. Results of bacterial sampling indicate that, in general, areas with shallow groundwater had a higher percentage of bacterial contamination. Volatile organic chemical (VOC) analysis did not indicate that unsewered areas were a significant source of VOC contamination, but documentation of heavy metals and VOC contamination associated with septic systems serving commercial properties indicates that commercial properties on septic systems can cause contamination.

5.6.1 NITRATE-N SAMPLING RESULTS

A total of 567 nitrate-N samples were collected from private wells and monitoring wells during the study (excluding duplicates, splits and repeats). The number samples collected each quarter varied due to seasonal well access and the addition of several private wells and monitoring wells during the four quarters of sampling. During the first quarter, 142 samples were collected. During the second, third, and fourth quarters, 130, 141, and 154 samples were collected. The most recent nitrate-N data from 216 public water supply wells were also obtained. The nitrate-N sampling results are presented in map form on Attachment B, which shows the average nitrate value for private wells and monitoring wells, and the latest nitrate value for public water supply wells. The quarterly sampling results from private wells and monitoring wells are provided in Appendix A. The latest results obtained for public water supply wells are provided in Appendix B.

Quality Assurance/Quality Control:
Nitrate samples collected from private wells and monitoring wells were analyzed by Dr. Juday at the University of Montana Chemistry Department. Split samples were taken periodically and sent to the Montana Department of Health and Human Services Chemistry Laboratory for analysis. Appendix C includes the results for nitrate split sampling.

In addition to split sampling, duplicate samples, blanks and standards were also submitted to Dr. Juday for quality assurance/quality control (QA/QC). Duplicate samples were periodically taken to check laboratory precision. Known standards obtained from the University of Montana Geology Department were submitted to check laboratory accuracy. Bottle blanks, consisting of washed bottles filled with deionized water were submitted to verify that bottle washing practices were sufficient.

The results of the QA/QC procedures indicate the data are reliable. A total of four bottle blanks were submitted to verify that the bottle washing procedures for each quarter of sampling were sufficient. Each round of sampling showed <0.01 mg/l nitrate, indicating that the bottle washing procedures were acceptable. Two nitrate-N standards submitted to Dr. Juday during the first quarter of sampling indicated that laboratory accuracy was good. The results for the two standards submitted are presented in Table 23.

TABLE 23
Results of QA\QC Nitrate Standards

LAB	DATE	ID	STANDARD (mg/l)	RESULT (mg/l)	DIFFERENCE	RPD (%)
UM	06/07/94	175	0.25	0.24	0.01	4.08
UM	06/07/94	174	1.00	0.95	0.05	5.13

A total of 12 duplicate samples were submitted to both laboratories for QA/QC. The results for duplicate analysis are presented in Table 24, and indicate that the laboratory precision was good. Results for sample splits were also good, and are presented in Appendix C.

Limited repeat sampling was also completed during the last quarter of sampling in Spring, 1995. Repeat sampling was conducted to evaluate variations in nitrate levels over short time periods. Four sampling sites were sampled twice on different days within a two week period. The results for repeat samples are presented in Table 25. For three of the sites, the variability was small. Site #97 varied significantly, and the cause of this variation is unknown. Daily variations in septic system discharge near a sampling point, or changes in groundwater flow paths could account for this variation.

TABLE 24
Results of QA\QC Duplicate Samples

LAB	DATE	SAMPLE #'S	SAMPLE 1 (mg/l)	SAMPLE 2 (mg/l)	DIFFERENCE	RPD (%)
DHES	06/13/94	90, 90D	2.63	2.81	0.18	6.62
DHES	06/13/94	42, 42D	0.45	0.47	0.02	4.35
UM	6/8/94	32, 32D	0.24	0.30	0.06	22.2
UM	6/8/94	122, 122D	0.87	0.87	0	0
DHES	6/27/94	191 191D	0.68	0.69	0.01	1.5
UM	8/17/94	114, 114D	0.89	0.89	0	0
UM	8/23/94	192, 192D	0.54	0.53	0.01	1.9
UM	2/1/95	76, 76D	1.48	1.49	0.01	0.7
UM	2/6/95	202, 202D	1.40	1.40	0	0
UM	2/8/95	6, 6D	0.68	0.67	0.01	1.5
UM	5/10/95	111, 111D	0.74	0.74	0	0
UM	5/11/95	106, 106D	0.77	0.77	0	0

TABLE 25
Results of repeat sampling for nitrates

WELL ID#	DATE/NO_3(mg/l)	DATE/NO_3(mg/l)	% DIFFERENCE
85	5/10/95, 0.54	5/22/95, 0.57	5.3%
97	5/9/95, 0.61	5/24/95, 0.97	59.0%
133	5/10/95 0.41	5/22/95, 0.44	6.8%
173	5/12/95, 9.7	5/23/95, 9.5	2.1%

Summary of Nitrate Data By Area:
The nitrate values obtained from private wells during the study ranged from <0.01 to 13.5 mg/l. The 13.5 mg/l result was from one of the 11 wells in the older Linda Vista subdivisions that are being monitored for the Montana Department of Environmental Quality. In general, the highest results were obtained in the Linda Vista area. The highest nitrate level recorded in a private well sampled for the study was 3.82, in a well located near Linda Vista.

Nitrate data obtained from a new well installed near the junction of Upper and Lower Miller Creek Road, along the edge of the Bitterroot River floodplain, showed a value of 6.85 mg/l. This well was not one of the wells sampled for the study, but it was collected by the well owner during the period of the study. Outside the Linda Vista area, none of the wells sampled approached the drinking water standard of 10 mg/l nitrate. In general the nitrate values shown on Attachment B indicate that the highest nitrate values occur in areas with lower hydraulic conductivity. Areas with higher hydraulic conductivity have more water moving through the area, which can dilute contaminants.

Cumulative impacts from septic systems were documented in the unsewered areas studied. The most dramatic water quality impacts were measured in the Westview Park area. Groundwater up gradient of Westview Park had nitrate levels below 0.25 mg/l, while groundwater down gradient of the Park had nitrate levels above 2.50 mg/l. Cumulative impacts also appear to be present in the West Riverside and East Missoula areas, based on changes in water quality up gradient and down gradient of the areas. Groundwater in a domestic well located on the east side of West Riverside had nitrate levels below 0.25 mg/l, while a monitoring well directly down gradient of the area showed nitrate levels above 0.75 mg/l.

Attachment B also shows cumulative impacts in the Missoula urban area, north and south of the Clark Fork River. South of the River, nitrate levels increase as groundwater flows southwest towards the Bitterroot River. Impacts from the East Reserve Street area appear to be present based on a comparison of nitrate levels up gradient and down gradient of the area (see Attachment B). North of the Clark Fork River, groundwater in Northside area appears to be degraded by groundwater recharge from the Rattlesnake Valley.
The average nitrate value for each unsewered area was calculated using the data input into GIS. The results were used to rank the unsewered areas in order, from highest to lowest average nitrate value. The average nitrate values and the final ranking for each area is presented in Table 26.

TABLE 26
Average nitrate concentration in unsewered areas

AREA	AVERAGE, MWC WELLS	AVERAGE, PUBLIC WELLS	AVERAGE WQD WELLS	AVERAG E VALUE	FINAL RANK
East Missoula	0.42, *(2)	1.01 (5)	1.10 (2)	0.90	5
East Reserve	0.54, (3)	0.52 (19)	0.61 (12)	0.55	3
Lolo	no wells	1.16 (10)	0.50 (1)	1.10	6
Mullan	no wells	1.33 (10)	1.02 (9)	1.18	7
Rattlesnake	no wells	no wells	1.41 (11)	1.41	8
West Reserve	1.30, (1)	0.87 (7)	0.89 (51)	0.89	4
West Riverside	no wells	0.41 (16)	0.29 (5)	0.38	2
Westview Park	no wells	0.05 (2)	no wells	0.05	1

*(x) number of wells sampled, All values are in mg/l

5.6.2 EVALUATION OF NITRATE TRENDS

To evaluate possible trends in nitrate levels for the study, access to 30 domestic wells sampled by Juday and Keller (1978) and 10 domestic wells and monitoring wells sampled by Woessner (1988) was obtained. Review of the data does not indicate a clear trend. Some sites show significant increases and decreases. Due to the limited data set and the multiple variables that can affect nitrate levels, it was determined that the nitrate data do not show a significant trend. The results for wells tested for this study that were also tested by Juday and Keller (1978) and Woessner (1988) are presented in Appendix C.

5.6.3 BACTERIA SAMPLING

A total of 554 bacterial samples were collected from private wells (excluding repeat samples). Samples were analyzed for coliform and fecal coliform bacteria. The monitoring wells used for the study were not sampled for coliform bacteria because the well casings were not sealed and the sampling techniques were non-sterile. Public water supply well data for bacteria were also not used since some public systems chlorinate their water supply, and if a system gets a positive bacteria result, immediate chlorination and re-sampling is required.

Table 27 shows the number of wells sampled each quarter, the number of positive samples, and the percentage of positive samples. For all four quarters, an average of 9.4 % of the samples were positive for coliform and non-coliform bacteria. The percentage of contaminated samples was 15.3% during the summer sampling period, roughly double the percentage during the rest of the year. This may indicate a higher degree of bacterial contamination during the period when the water table is highest, corresponding to peak flows in rivers, streams and irrigation ditches.

TABLE 27
Bacteria sampling results for private wells

QUARTER (SEASON)	# SAMPLES	# POSITIVE	% POSITIVE
1ST (Spring)	137	12	8.8
2nd (Summer)	131	20	15.3
3rd (Fall/Wtr)	137	10	7.3
4th (Wtr/Spring)	149	10	6.7

Coliform and non-coliform bacteria were detected in private wells. One private well in the Rattlesnake Valley tested positive for fecal coliform bacteria during one quarter. Three private wells were consistently contaminated, even after the well owners were instructed to chlorinate their well systems. Although statistical tests were not used, mapping of positive bacterial results indicate that a higher percentage of contaminated wells were located in areas of shallow groundwater. Bacterial data were very limited in the East Missoula and Lolo areas due to a lack of access to private wells for sampling. Because some areas were not sufficiently sampled for bacteria, and because of the many factors that can contribute to bacterial contamination, the areas were not ranked based on bacterial data.

Appendix A contains the bacterial sampling results for each quarter. Attachment C is a map showing the results for bacterial samples collected during the study. The map shows the boundaries of the unsewered areas, the types of bacterial contamination present and the regional groundwater flow directions. If a site had various types of bacterial contamination, the type of contamination with the highest risk factor was shown. For example if a site was contaminated with coliform bacteria during two quarters and fecal coliform once, the fecal coliform result is shown.

5.6.4 VOC SAMPLING

The purpose of conducting volatile organic compound (VOC) sampling was to determine if areas served by septic systems were a significant source of VOC contamination. Numerous household products contain VOCs, and if improperly disposed of into a septic system, these products can cause groundwater contamination. In addition, commercial businesses that use septic systems and generate wastewater containing VOCs may be a source of contamination if the wastewater is discharged into a septic system. The sampling for VOCs conducted in unsewered residential areas did not detect significant VOCs above background levels.

A total of 11 private wells and four monitoring wells in unsewered areas were sampled in Summer, 1994. Results of initial sampling of 10 private wells indicated that seven were contaminated with chloromethane. This VOC is very volatile, and is not commonly found in groundwater. The District is unaware of this compound ever being detected in Missoula area wells. Because of the possibility of laboratory error or sample contamination, three of the seven wells with the highest concentrations of chloromethane were re-sampled, along with four monitoring wells. The second round of sampling did not detect any chloromethane, and the initial results were considered to be false.

Of the wells sampled for VOCs, three were located in the West Reserve Street area, two were located in the East Reserve Street area, two were in the Rattlesnake Valley and one was located in East Missoula. One of the wells in the East Reserve Street area tested positive for perchloroethylene at 1.45 parts per billion (ug/l). This well is located near Southgate Mall, and is within an area of known regional perchloroethylene contamination. The only other contaminated well was a monitoring well at the mouth of the Rattlesnake Valley, which contained 1.46 ug/l chloroform and 0.71 ug/l bromodichloromethane. The source of these compounds is unknown. The monitoring well is located in Gregory Park.

The potential threat of commercial businesses causing VOC contamination of groundwater was demonstrated during the study period when a furniture refinishing business in the East Reserve Street area was found to be discharging approximately 100 gallons/month of rinse water containing methylene chloride into a septic tank connected to a seepage pit. Investigation and remediation of this site is ongoing, and demonstrates the potential for contamination of groundwater from commercial businesses using septic systems. Two other businesses, an engine rebuilder and an electroplating business, both in the East Reserve Street area, have also been found to have discharged wastes containing VOCs and other hazardous chemicals into seepage pits.

5.7 GROUNDWATER FLOW PATTERNS IN UNSEWERED AREAS

The regional groundwater flow patterns for each unsewered area were determined to evaluate potential down gradient impacts. The regional flow patterns are presented on Attachments B and C, which show the nitrate and bacteria sampling results. Information on groundwater flow directions around the East and West Reserve Street areas was obtained from Peery (1988), Miller (1990) and Armstrong (1991). Groundwater flow directions for the Mullan Road area and Westview Park was obtained from Smith (1992) and Pottinger (1988). A study completed for ARCO, of the hydrogeology from

Milltown Dam to the mouth of Hellgate Canyon, was used to determine groundwater flow directions for West Riverside and East Missoula (Land & Water Inc, 1994).

No groundwater flow maps were available for the Rattlesnake Valley and Lolo. In these two areas regional groundwater flow directions were determined by evaluating surface water flow, topography and geology. For areas where seasonal groundwater surface contour maps (potentiometric maps) were available, flow directions during the Spring were used. The rationale is that public health risks from groundwater contamination are higher when the depth to the water table is shallow.

Groundwater flow in the Rattlesnake Valley was assumed to generally be south, following the slope of the valley floor, and discharging into the main aquifer in the area of the Van Bureau Street Bridge. No significant up gradient sources of nitrate were identified for the Rattlesnake Valley aquifer. The alluvial aquifer in the Rattlesnake Valley is bounded on the east and west sides by bedrock and clay-rich foothills. Once groundwater leaves the Rattlesnake Valley, the majority of the water is believed to stay north of the Clark Fork River, flowing northwest through the downtown area and West Broadway area. This assumption is based on potentiometric maps for the area (Miller, 1990) and nitrate sampling data.

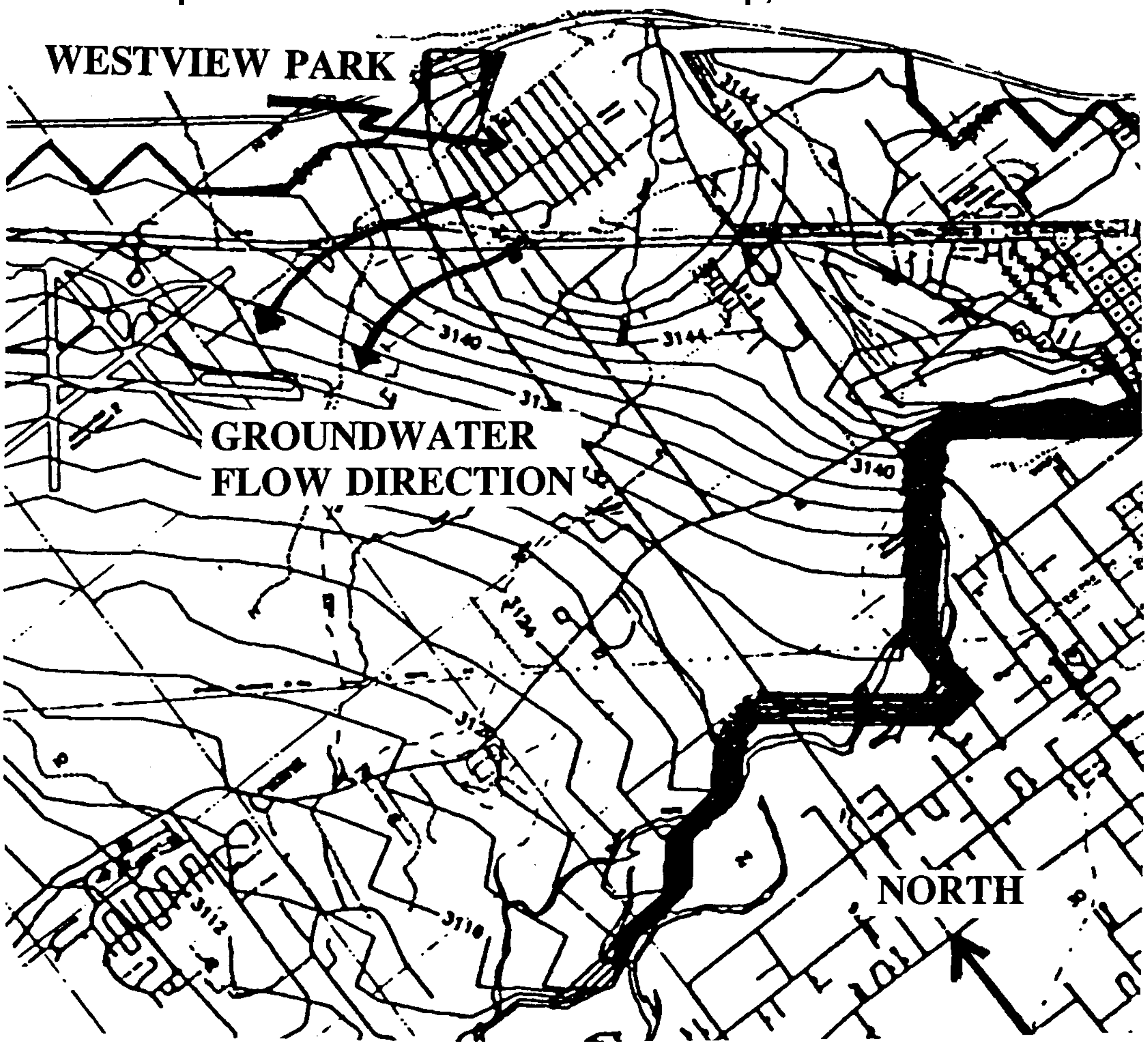
Groundwater flow direction in Lolo is assumed to follow the general direction of the Bitterroot River Valley, flowing north and then northwest towards Missoula. Groundwater from the Lolo Creek Valley is also assumed to flow north once it reaches the mouth of Lolo Creek. Unsewered developments to the south of Lolo in the Bitterroot Valley, and unsewered development along Lolo Creek may impact nitrate levels in wells north of Lolo Creek in the Bitterroot Valley.

The regional flow patterns around Westview Park are dominated by groundwater recharge from the Grant Creek alluvial aquifer. In the area of the Grant Creek alluvial fan, at the mouth of the Grant Creek Valley, groundwater flow patterns tend to mimic the slope of the fan. Westview Park is located on the west side of the alluvial fan, and groundwater flows due west towards the airport, and then swings west/southwest. The regional flow patterns around Westview Park are based on modeling completed by Pottinger (1988), and regional mapping by Smith (1992). A modeled potentiometric surface map for the Westview Park area, completed by Pottinger (1988) is shown in Figure 12. Public water supply wells in Grant Creek, and to the south and north of Westview park, all have nitrate levels below 0.25 mg/l. All three private wells, located due west and southwest of Westview Park, had nitrate levels above 2.50 mg/l.

Groundwater flow in the Mullan Road area is generally due west, and then swings towards the northwest. The Clark Fork River appears to represent a general no flow boundary, with flow paralleling the river. Based on this fact, up gradient sources of nitrate for the Mullan Road area include north Reserve

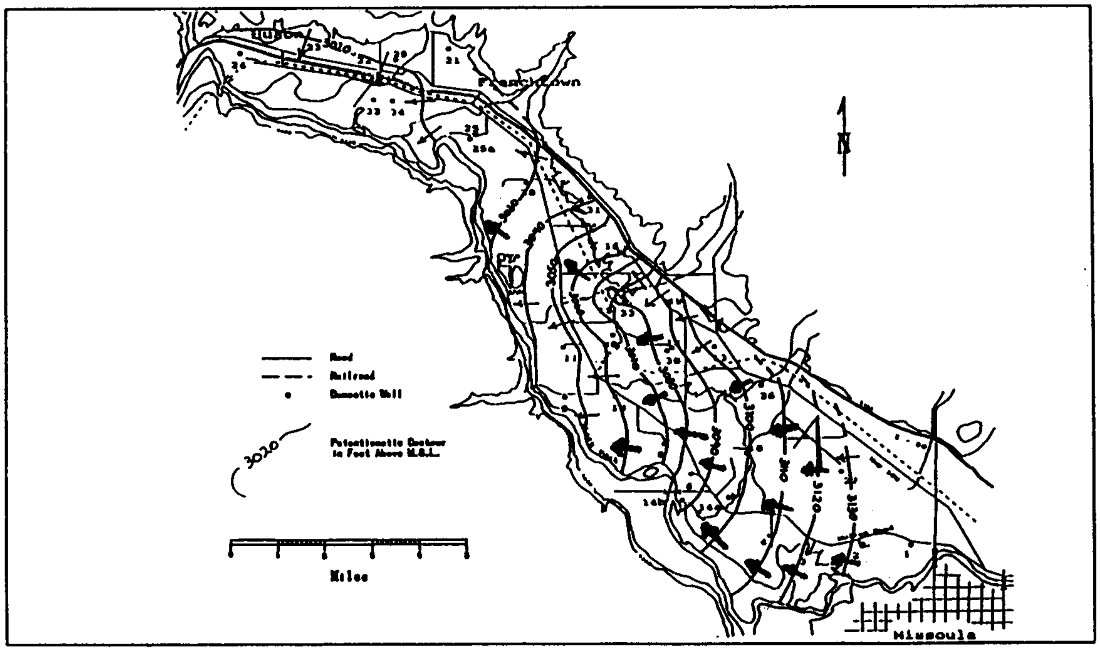
Street, West Broadway, the Northside, the Downtown area and possibly the Rattlesnake Valley. Groundwater from all three areas eventually ends up recharging the Clark Fork River to the west. Figure 13 shows the potentiometric surface for the aquifer in the Mullan Road area.

FIGURE 12
Computer Modeled Potentiometric Map, Westview Park



Source: Pottinger, (1988)

FIGURE 13
Regional Groundwater Flow for the Mullan Road area

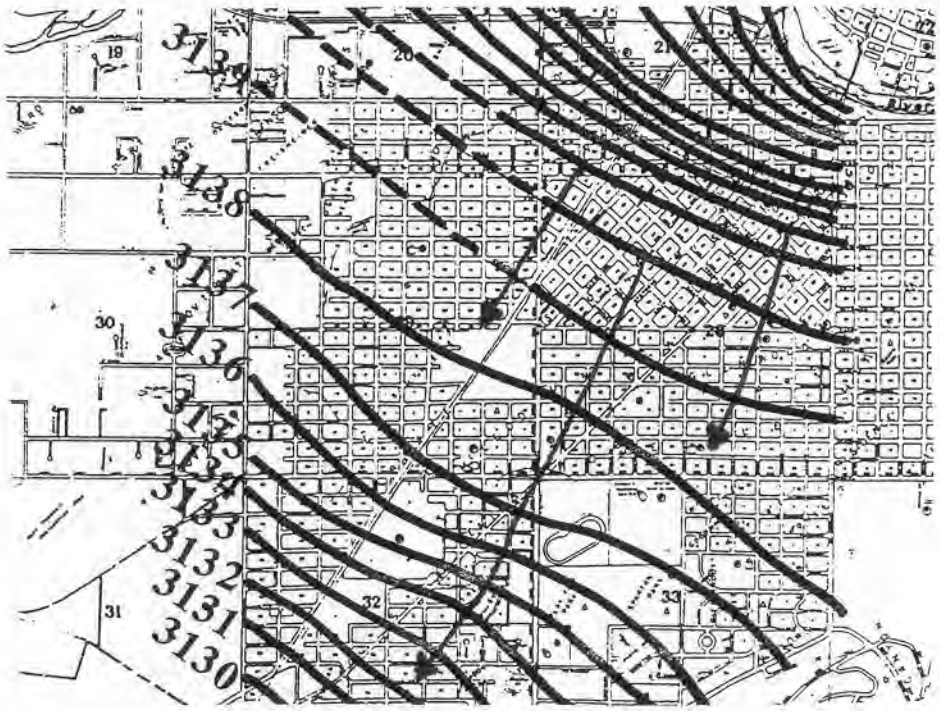


Source: Smith (1992)

Regional groundwater flow paths for the East and West Reserve Street areas were determined based on Miller (1990) and Armstrong (1991). Armstrong provides detailed groundwater table contour maps based on measurements of 41 wells in the East Reserve Street Area. Based on his work, regional groundwater flow is to the southwest. Figure 14 shows the June, 1990 potentiometric surface map for the East Reserve Street area.

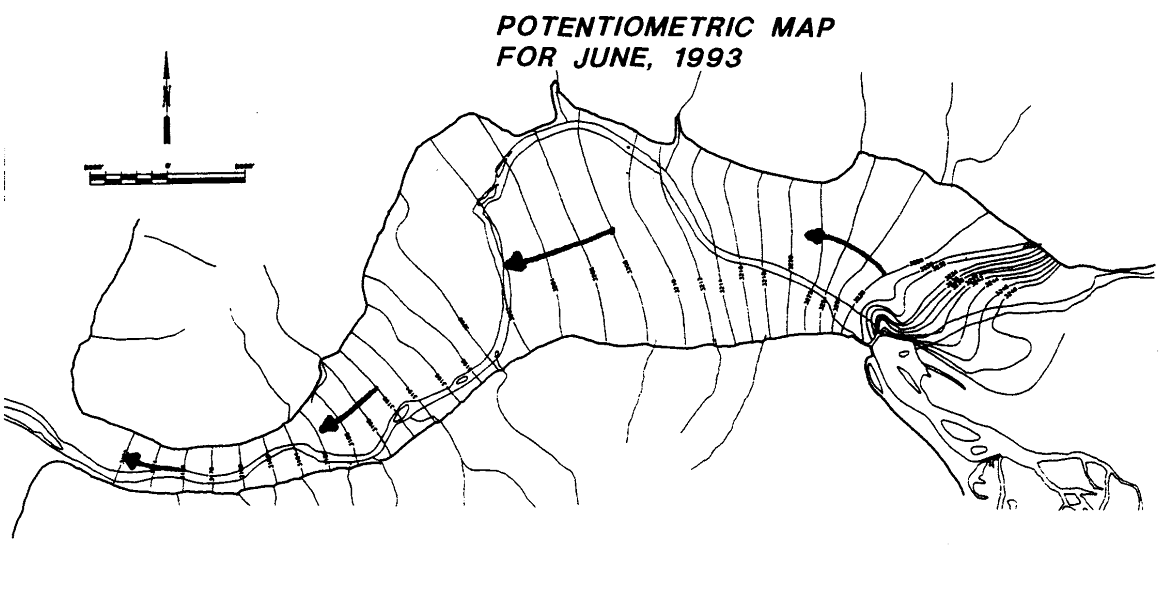
The primary up gradient source of nitrate for both the East and West Reserve Street areas is the urban area to the east, on the south side of the Clark Fork River. Groundwater flow direction in the West Reserve Street area is west/southwest based on Miller (1990). Groundwater from East and West Reserve Street areas discharges to the Bitterroot and Clark Fork Rivers. Groundwater flow paths for East Missoula and West Riverside were determined based on Land & Water Consulting Inc. (1994), and are shown in figure 15. Groundwater from the West Riverside area flows west/northwest and then swings southwest towards East Missoula. There are no significant up gradient nitrate sources for the West Riverside area. Groundwater flow from East Missoula roughly parallels the Clark Fork River, flowing southwest into Hellgate Canyon. West Riverside and other unsewered lots in the area to the east of East Missoula may impact nitrate levels in East Missoula.

FIGURE 14
Regional groundwater flow in the East Reserve Street area



Source: Armstrong (1991)

FIGURE 15
Regional groundwater flow for East Missoula and West Riverside



5.8 LOCATIONS OF PUBLIC AND PRIVATE WELLS

The locations of all private wells and monitoring wells sampled for the study, and the locations of all public water supply wells in the study area are presented on Attachment B. Public water supply wells are shown with larger symbols. The locations of all water supply wells for which drillers logs have been filed with the Montana Bureau of Mines and Geology are shown on Attachment D.

A total of 216 public water supply wells were identified and mapped for the study, including 34 wells operated by Mountain Water Company in the Missoula urban area. Within the boundary of the Missoula Valley Water Quality District, a total of 3,771 well records were obtained. Of these, 1,612 (43%) wells were located within the boundaries of the eight unsewered areas. Table 28 shows the number of well logs reported for each unsewered area, the size of the unsewered area, the overall well density (wells/square mile) and the final ranking value assigned for well density within unsewered areas.

TABLE 28
Well densities in unsewered areas

UNSEWERED AREA	WELL LOGS	AREA $miles^2$	$WELLS/MI^2$ DENSITY	WELL RANKING
East Missoula	65	0.75	87	5
E. Reserve St.	195	2.0	98	6
Lolo	121	2.0	61	3
Mullan Road	265	4.25	62	4
Rattlesnake	102	2.25	45	2
W. Reserve St.	717	4.75	151	8
West Riverside	145	1.0	145	7
Westview Park	2	0.25	8	1

West Reserve Street and West Riverside had the highest overall well densities. The West Reserve Street area had by far the greatest total number of wells, with 717 (44%) well logs on file. Westview Park only had two reported wells, which are the public water supply wells for the park. The East Reserve Street area had a relatively high density of wells, but the majority of the wells are located north of Third Street. The majority of septic systems in the East Reserve Street area are located south of Third Street.

5.9 DRASTIC ANALYSIS/HYDROGEOLOGY IN UNSEWERED AREAS

The overall vulnerability of the aquifer to septic systems was evaluated and ranked based on the DRASTIC values determined for each area. The DRASTIC analysis was completed for the area included within the Missoula Valley Aquifer Protection Ordinance boundary, which covers 140 square miles. A map showing the final DRASTIC values within the study area is included as Attachment E. The input data used for the DRASTIC analysis are available for review at the Water Quality District office. Attachment E shows the relative DRASTIC values assigned to each quarter/quarter section in the area evaluated, which consists of the area covered by the Missoula Valley Aquifer Protection Ordinance. Most of the West Reserve Street area, the eastern half of the Mullan Road area and the northern half of the East Reserve Street area are in areas with the highest DRASTIC rating for aquifer sensitivity. Westview Park is in the area of some of the lowest DRASTIC values, based on the available data. Hydraulic conductivity values in this area may be higher than the values used in the analysis, which would increase the DRASTIC values for Westview Park.

The average DRASTIC value for each area was calculated using the GIS data. The areas were then ranked based on the average DRASTIC value for each unsewered area. The average DRASTIC values and the final DRASTIC ranking value assigned for each area are presented in Table 29. The higher the DRASTIC value, the more susceptible the area is to pollution from septic systems. The West Reserve Street area had the highest DRASTIC rating, followed by the East Reserve Street area. The Mullan Road area would have been assigned a higher value if the western portion of the area, which is over a layer of glacial lake Missoula sediments, was not included.

TABLE 29
Average DRASTIC values in unsewered areas

AREA	AVERAGE DRASTIC VALUE	FINAL DRASTIC RANKING
East Missoula	106.4	2
East Reserve Street	148.4	7
Lolo	129.4	6
Mullan Road	123.4	5
Rattlesnake Valley	107.8	3
West Reserve Street	151.2	8
West Riverside	108.1	4
Westview Park	71.0	1

It is important to note that the DRASTIC (C)onductivity factor is inversely related to average nitrate values in the study area. Areas with high hydraulic conductivity receive a higher DRASTIC rating, but due to the high conductivity, dilution of nitrate is greater. It is also important to note that although areas of higher hydraulic conductivity have lower nitrate values, microbial and chemical contaminants can travel further and faster due to the higher conductivity values.

6.0 FINAL RANKING OF UNSEWERED AREAS

The final ordinal ranking for each unsewered area and a ranking of the highest density quarter sections is presented below. The ranking of the highest density quarter sections is provided for additional information, to highlight localized high density unsewered subareas within the eight areas evaluated. The final ordinal ranking of the eight unsewered areas is not based on the ranking of the highest density quarter sections.

6.1 FINAL ORDINAL RANKING

The final ordinal ranking for the unsewered areas was determined by summing the ranking scores for each of the eight factors considered. The eight ranking categories were used to evaluate specific impacts from septic systems. The ranking for the percentage of commercial units was used to evaluate the relative risk of groundwater contamination from non-sanitary discharges. Septic system density ranking was used to evaluate the volumes of sewage discharged per quarter section, and potential impacts to water quality and public health. The ranking for percentage of replacement septic system permits was used to evaluate failure rates and public health risks due to exposure to surfacing sewage. The percentage of seepage pit systems in each area was used to evaluate the relative level of septic system treatment, based on documentation that seepage pits provide less treatment than drainfields. The average nitrate values for each area were used to evaluate the relative nitrate levels, indicating dilution potential and overall levels of sewage contamination. Well density was used to evaluate potential public health risk due to contamination in each area. Cumulative impacts to surface water and groundwater from septic systems was ranked based on the relative loading of sewage from each area. Finally, the vulnerability of the aquifer to contamination from septic systems in each area was ranked based on the average DRASTIC value obtained for each area.

In summary, the factors considered, and the final ranking for each factor are presented in Table 30. For this analysis, all of the factors were weighted equally. This was based on the lack of sufficient data to suggest any one factor was more important than the other.

TABLE 30
Final ordinal ranking of unsewered areas

AREA	COMMERCIAL UNITS	SEPTIC DENSITY	LOADING	% SEEPAGE PITS	REPLACEMENT	AVG. NO_3	WELLS DENSITY	DRASTIC	FINAL SCORE
EAST MSLA.	7	7	5	7	4	5	5	2	42
EAST RESERVE	8	6	8	6	7	3	6	7	51
LOLO	5	2	2	2	3	6	3	6	29
MULLAN ROAD	4	1	4	1	1	7	4	5	27
RATTLE-SNAKE	2	3	6	4	8	8	2	3	36
WEST RESERVE	3	4	7	3	6	4	8	8	43
WEST RIVERSIDE	6	5	3	5	5	2	7	4	37
WESTVIEW PARK	1	8	1	8	2	1	1	1	23

Based on the summation of the ordinal rankings for the eight factors considered, the unsewered areas are ranked below in order of impact to water quality and public health risk. If the areas were sewered based just on the threat to the groundwater and surface water resources and public health risks, the recommended prioritization is as follows:

AREA	**FINAL SCORE**	**PRIORITY**	
East Reserve	**51**	**1**	**HIGHEST**
West Reserve	**43**	**2**	
East Missoula	**42**	**3**	
West Riverside	**37**	**4**	
Rattlesnake	**36**	**5**	
Lolo	**29**	**6**	
Mullan Road	**27**	**7**	
Westview Park	**23**	**8**	**LOWEST**

6.2 RANKING OF HIGHEST DENSITY QUARTER SECTIONS

In addition to evaluating and ranking the eight unsewered areas by averaging the date for the eight factors considered, 14 quarter sections that have septic system densities greater than one per acre (160 unsewered units/quarter section) were also evaluated and ranked. This evaluation and ranking was completed to identify and better represent specific high density unsewered quarter sections contained within high density unsewered areas. The quarter sections were selected for evaluation based on current health standards, which allow for a maximum septic system density of one system per acre, within a subdivision using private wells. If public water is supplied, up to two septic systems per acre are allowed within a subdivision. Because private wells are located within or down-gradient of all the unsewered areas, and most of the systems in the unsewered areas are do not meet current design standards, the health standard of one septic system per acre was used as a cut off for selecting quarter sections for evaluation and ranking.

Of the 14 high density quarter sections evaluated, one is located in the East Missoula area, four are located in the East Reserve Street area, two are located in the Rattlesnake area, four are located in the West Reserve Street area, two are in the West Riverside area, and one is represented by the West View Park area. Attachment F shows the locations of the 14 quarter sections evaluated. The Mullan Road and Lolo areas did not contain any quarter sections with a density greater than 160 units/quarter section.

Four quarter sections have septic system densities greater than two systems per acre. Two of these quarter sections are located in the East Reserve Street area, one is located in East Missoula, and one is located in Westview Park.

The quarter sections were evaluated and ranked using the same methods used for the unsewered areas, with the exception that average nitrate-N concentrations in groundwater was not used and cummulative impacts/nitrogen loading was not used. The average nitrate-N values were not ranked due to the limited nitrate data available at the scale of individual quarter sections. For example, there were no wells sampled in one of the quarter sections in the Rattlesnake Valley (see Attachment B). Cummulative impacts/nitrogen loading was not used because the ranking would be the same as the septic system density mapping since all the areas are the same size (160 acres). Using the loading factor would effectively double the weighting for septic system density.

The order of prioritization, the ordinal ranking score, the values used to rank quarter section and the final scores are presented in table 31. The area each quarter section is located in is also presented in Table 31. The location of each quarter section and the prioritization are also presented on Attachment F.

Based on the quarter section ranking, the three highest ranked quarter sections are located in the East Reserve Street area. The fourth highest ranked quarter section was in East Missoula. This quarter section has the highest density with 542 commercial and residential units on septic systems.

TABLE 31
Final ordinal ranking of highest density quarter sections

PRIORITY	AREA	COMMERCIAL UNITS	SEPTIC DENSITY	PERCENT SEEPAGE	PERCENT REPLACEMENT	WATER WELL DENSITY	DRASTIC	FINAL SCORE
1	EAST RES.	13 (44)	13 (540)	11 (81)	12 (21)	2.5 (4)	10 (145)	62.5
2	EAST RES.	11 (11)	10 (310)	12 (87)	13 (22)	4 (7)	8.5 (143)	59.5
3	EAST RES.	10 (9)	9 (296)	10 (76)	9 (18.6)	7 (17)	13 (155)	59
4	EAST MSLA	12 (21)	14 (542)	13 (89)	3 (8.7)	8 (24)	6 (132)	57
5	EAST RES.	14 (54)	11 (363)	7.5 (66)	6 (12.4)	5 (13)	8.5 (143)	52
6	WEST RIV.	7.5 (5)	8 (210)	9 (71)	8 (14.8)	12 (33)	2 (111)	47.5
7	WEST RES.	4 (1)	3 (167)	7.5 (66)	7 (13.2)	10 (30)	12 (148)	43.5
8	R. SNAKE	7.5 (5)	7 (190)	6 (59)	14 (33.7)	2.5 (4)	5 (119)	42
9	WEST RES.	1.5 (0)	6 (187)	3 (46)	10 (18.7)	14 (51)	7 (141)	41.5
10	WEST RES.	6 (3)	4 (175)	5 (54)	4 (9.7)	11 (31)	11 (147)	41
11	WEST RES.	4 (1)	5 (177)	1 (28)	5 (10.7)	9 (29)	14 (158)	38
12	WEST RIV.	9 (6)	2 (164)	4 (50)	2 (6.1)	13 (37)	3 (116)	33
13	WEST VIEW	4 (1)	12 (364)	14 (93)	1 (4.7)	1 (2)	1 (55)	28
14	R. SNAKE	1.5 (0)	1 (163)	2 (45)	11 (19.0)	6 (15)	4 (118)	25.5

7.0 SUMMARY BY AREA

The following information summarizes the results for each area. The order that the areas are listed in matches the order of the final priority ranking in Section 6.1.

East Reserve Street (1st Priority);
The East Reserve Street area ranked well above the other areas overall, with a final ranking score of 51, compared to the next highest score of 43 for the West Reserve Street area. This area has the highest total number of commercial units (211) and the highest overall percentage of commercial units (6.9%). For density of commercial units, the area was assigned an ordinal ranking score of 8. There are three known commercial properties where disposal of chemical waste into septic systems has been documented. Two of these businesses are State Superfund sites.

The area was assigned an ordinal ranked score of 7 for overall septic system density, with a density of 1.54 units/acre. The total number of commercial and residential units in this area is 3041, with 1977 (65%) units on septic systems. It contains the second highest density quarter section in the Water Quality District, with 540 unsewered units in one quarter section (160 acres).

Since the cumulative impact/nitrogen loading factor was based on the total number of units on septic systems, the East Reserve Street area also ranked highest for cumulative impacts and total nitrogen loading. The area contributes an estimated 395,400 gallons/day of sewage (14.4 million gallons/year) and 165 pounds/day (60,225 pounds/year) of nitrogen to the subsurface.

Based on septic system permit records, 73% of the permitted septic systems in this area use seepage pits. Because many systems in the area were built prior the requirement for permits, and these systems were built using cesspools or seepage pits, the percentage of substandard systems is probably much higher than 73%. The area was assigned an ordinal ranking score of 6 for the percentage of seepage pits. Records indicate that there have been 378 replacement septic system permits issued for this area, with a replacement percentage of 19.1%. This was the second highest replacement percentage among the eight areas. Due to limited lot sizes in the area, 73% of the replacement permits issued in this area since 1990 have been for seepage pits.

The average nitrate-N concentration in groundwater, based on field sampling and public water supply data, is 0.55 mg/l. This value is well below the drinking water standard of 10 mg/l, and appears to be related to dilution due to the high hydraulic conductivity of the aquifer in this area, and the limited number of up-gradient septic systems. Bacterial sampling results are limited in this area, but there was one well owned by a church in the area that had persistent coliform bacteria contamination. Two wells near the Clark Fork river also showed coliform bacteria contamination (see attachment C). Groundwater from the East Reserve Street Area flows southwest into the West Reserve Street area.

Records for well logs indicate that there are 96 wells in the area, including 22 public water supply wells. This area has the highest total number of public water supply wells for the unsewered areas evaluated. Many of these wells are in the northern portion of the area, and the southern portion of the area is served by public water. Overall well density in the area is 98 wells/mile^2. The area was assigned a relatively high ordinal ranking score of 6 for well density.

The East Reserve Street was assigned an ordinal ranking score of 6 for aquifer sensitivity, based on the DRASTIC analysis. The high value was assigned due to very coarse soils, high hydraulic conductivity and relatively shallow depths to groundwater.

The ranking of high density quarter sections indicates that four of the 14 highest density quarter sections are in the East Reserve Street area. The four quarter sections ranked first, second, third and fifth in priority (see Attachment F).

West Reserve Street (2nd Priority);
The West Reserve Street area received an overall final score of 43. This is very close to the final ranking for East Missoula, which had a final score of 42. This indicates that overall, these two areas are similar in terms of water quality impacts and public health concerns.

There is a total of 1976 units within the West Reserve Street area, and of these, 1883 (95%) are connected to septic systems. The percentage of commercial properties in this area was low, with 1.0% (19 units) of the total units in the area listed as commercial. The area was assigned a low ordinal ranking score of 3 for percentage of commercial properties. The overall septic system density in this area is less than half the overall density of the East Reserve Street area. Overall density is 0.62 units/acre, and the area was assigned an ordinal ranking score of 4 for septic system density.

Cumulative impact/nitrogen loading calculations for the West Reserve Street area indicate that the area contributes 376,600 gallons/day (134 million gallons/year) of sewage and 157 pounds/day (57,305 pounds/year) of total nitrogen to the subsurface. The area was assigned a relatively high ordinal ranking score for cumulative impacts/nitrogen loading of 7. The literature review indicates that groundwater from this area discharges to the Bitterroot River, contributing up to 50% of the soluble nitrogen loading to the river in the summer (Ingman, 1992).

The percentage of seepage pits based on septic system permit records in this area is 36% and the area was assigned an ordinal ranking score of 3 for percentage of seepage pits. This is significantly lower than the East Reserve Street area. The percentage of replacement septic systems in the West

Reserve Street area, based on septic system permit records, is 16.6%. For this factor the area was assigned an ordinal ranking score of 6.

The average nitrate-N level in groundwater in the area was 0.89 mg/l nitrate-N. This is low compared to the standard, but higher than levels in the East Reserve Street area. Some of this increase is probably related to cumulative impacts from the East Reserve Street area. Limited historical nitrate sampling data from 1965 indicates that nitrate levels have increased since 1965.

Most of the West Reserve Street area is served by private wells, and the area was assigned the highest ordinal ranking score of 8 for this factor. Records indicate that there are 717 wells in the area, with an overall density of 151 wells per square mile. Records also indicate there are eight public water supply wells in the area.

Due to shallow groundwater in this area, along with coarse soils and high hydraulic conductivity values, this area ranked highest in the DRASTIC analysis for aquifer sensitivity. The North Missoula and South Missoula septic system study sites instrumented by Woessner et al. (1995), were both shown to be in areas where groundwater rose to within five feet of the surface. Analysis of data from these study sites also suggests that septic system treatment is limited and effluent rapidly infiltrates to groundwater.

Many of the factors that present a risk of biological contamination are present in the West Reserve Street area, including shallow groundwater, coarse soils and high densities of private wells. A human enteric virus was isolated from groundwater under the septic system at the South Missoula study site by Woessner et al. (1995). Numerous wells in this area also tested positive for bacterial contamination (see Attachment C). Contamination appears to be related to shallow groundwater. Nitrate levels are relatively low due to the high hydraulic conductivities, but this same parameter increases the risk of microbial contamination of drinking water wells. A sanitary survey of private wells in this area, and more detailed biological water quality sampling should be completed in this area to assess the public health risk.

The West Reserve Street area also contains four of the 14 highest density quarter sections. These quarter sections ranked 7th, 9th, 10th and 11th in priority, mainly due to lower septic system densities. Densities in these quarter sections are significantly lower than quarter sections to the east in the East Reserve Street area.

East Missoula (3rd Priority);

Overall, the East Missoula area received a final ranking score of 42. This score was only one point lower than the final ranking score of 43 for the West Reserve Street area.

There are a total of 766 units in this area, and all of them are connected to septic systems. The East Missoula area was assigned an ordinal ranking value of 7 for percentage of commercial units, with records indicating there are 25 commercial properties (3.2%) in the area.

The area also received an ordinal ranked score of 7 for overall septic system density, with an overall density of 1.6 unsewered units/acre. The highest density quarter section in the Water Quality District is also in this area, with 542 unsewered units in one quarter section.

Based on the total number of unsewered units, the East Missoula area contributes 153,200 gallons/day (56 million gallons/year) of sewage and 64 pounds/day (23,360 pounds/year) of nitrogen to the subsurface. For this factor the area was assigned an ordinal ranking score of 5.

Based on septic system permit records, 76% of the systems in this area use seepage pits. For this factor the area was assigned an ordinal ranking score of 7. The percentage of septic system replacements was estimated to be 8.8%, and for this factor the area received an ordinal ranking score of 4.

The average nitrate-N level in groundwater in this area, based on domestic well sampling and public water supply data is almost the same as the West Reserve Street area, with an average concentration of 0.90 mg/l nitrate-N. The variability in nitrate-N levels however is greater than the variability in the West Reserve Street area. For this factor the area was assigned an ordinal ranking value of 5. There are seven public water supply wells in this area, including two large production wells operated by Mountain Water Company.

Overall well density was relatively low, with records showing a total of 65 wells in the area. The average density is 87 wells/mile^2. For well density the area received an ordinal ranking score of 5. Groundwater from the East Missoula area flows southwest into Hellgate Canyon.

The DRASTIC rating for East Missoula is relatively low, mainly due to the depth to groundwater and finer grained surface soils. For this factor the area was assigned an ordinal ranking score of 2.

The East Missoula area contains the 4th highest priority quarter section, based on the ranking of high density sections. This quarter section had the highest septic system density, with 542 unsewered units. In general, the East Missoula area represents an are with high septic system densities, a high percentage of commercial units, and a high percentage of seepage pit systems. It is also important to note that the East Missoula area is located in the recharge area for the Missoula Valley Aquifer. Water quality sampling in Hellgate Canyon, below East Missoula, indicates that nitrate-N values are elevated above background, but still relatively low compared to the drinking water standard (see Attachment B).

West Riverside (4th Priority);
The West Riverside area received a final ranking score of 37, which is only one point higher than the score assigned to the Rattlesnake Valley. This indicates that the water quality impacts and public health risks for these two areas are similar.

There area a total of 570 units in this area, and all the units are connected to septic systems. The area contains 17 commercial units and the percentage of commercial units is 3.0%. For this factor the West Riverside area was assigned an ordinal ranking score of 6.

Overall septic system density in the West Riverside area is 0.89 units/acre, with 570 units on septic systems within the area. For septic system density the area received an ordinal ranking score of 5. Based on the total number of units on septic, the West Riverside area was assigned an ordinal ranked number score of 3 for cumulative impacts/nitrogen loading. The area discharges an estimated 114,00 gallons/day (41.6 million gallons/year) of sewage and 48 pounds/day of total nitrogen (17,520 pounds/year) to the subsurface.

Records indicate that 68% of the permitted septic systems in the area are seepage pits. For this factor the area received a ranking score of 5. It is estimated that 10% of the septic systems in the West Riverside area have been replaced since 1967, and for this factor the area also received a ranking score of 5.

The average nitrate-N concentration in groundwater in the West Riverside area is 0.38 mg/l, and for this factor the area received a relatively low ranking score of 2. Water quality sampling in this area does suggest cumulative impacts. Wells located in the up-gradient portion of the area (to the east) show nitrate-N levels near background, while all wells down-gradient are clearly elevated above background. Groundwater from this area flows west/northwest towards East Missoula.

Well log records for the West Riverside area indicate there are 145 wells within the area evaluated, with an overall well density of 145 wells/mile^2. This includes 16 public water supply wells, mainly serving mobile home courts. for well density the West Riverside area was assigned a relatively high ordinal ranking score of 7.

Aquifer sensitivity based on the DRASTIC analysis for this area is moderate. For the DRASTIC factor this area received an ordinal ranking score of 4. This is mainly due to greater depth to groundwater.

The West Riverside area contains the 6th and 12th highest priority quarter sections based on the evaluation of high density quarter sections.

Rattlesnake Valley (5th Priority);
Overall the Rattlesnake Valley received a final score of 36, which is similar to the final score of 37 for the West Riverside area. There are a total of 1456 units within the area evaluated, and 825 (57%) are connected to septic systems. Assessors records indicate that there are 7 commercial properties in the area, but this number may not be accurate. For this factor the area received a relatively low ordinal ranking score of 2.

Septic system densities in the Rattlesnake vary more than other areas. The overall density of septic system in the area is relatively low, with a density of 0.57 units/acre. For this factor the area received a relatively low ordinal ranking score of 2. There are however, two high density quarter sections within the lower portion of the area which contain 163 and 190 unsewered units (1.02 to 1.19 unsewered units/acre).

Based on the 825 unsewered units in the area, the Rattlesnake discharges approximately 165,000 gallons/day (60.2 million gallons/year) of sewage to the subsurface, and contributes 69 pounds/day (25,185 pounds/year) of total nitrogen to the subsurface. For cumulative impacts/nitrogen loading the Rattlesnake area received a relatively high ranked score of 6. The only areas contributing more sewage to the subsurface were the East and West Reserve Street areas.

Based on septic system records, 58% of the septic systems in the middle and lower Rattlesnake Valley use seepage pits. For this factor the area received a moderate ordinal ranking score of 4. Records of septic system replacement permits for the Rattlesnake indicate that 23% of the septic systems have been replaced since 1967. This was the highest percentage of septic system replacements within the eight unsewered areas, and for this factor the area received a ranking score of 8.

The area also received the highest ordinal ranking score of 8 for average groundwater nitrate-N concentrations. Sampling data indicates that the average nitrate-N concentration in the area is 1.41 mg/l, well above the established background. In general water quality in the valley varied significantly, with some wells showing levels of nitrate-N below 0.25 mg/l and some wells with levels above 2.5 mg/l.

The only positive fecal coliform sample collected from domestic wells came from this area, and this area also contains a public water supply well that was abandoned by Mountain Water Company due to persistent bacterial contamination. Groundwater from the Rattlesnake Valley flows south, and recharges the main Missoula Valley Aquifer in the Hellgate Canyon area. Hydrogeologic reports and nitrate sampling data suggest that groundwater from the Rattlesnake Valley stays north of the Clark Fork River, and contributes to elevated nitrate-N levels in the North Side and West Broadway areas.

Records of well logs for the area indicate that there are 102 wells in the area, with an overall well density of 45 wells/mile^2. For this factor the area received a relatively low ordinal ranking score of 2. There are no active public water supply wells reported in the area.

The Rattlesnake area received a relatively low ranking score for aquifer sensitivity, based on the DRASTIC analysis. This was due mainly to the depth to groundwater and the relatively low hydraulic conductivity values reported for the valley. It is important to consider however, that DRASTIC does not take into consideration the total volume of groundwater moving through an area. Hydrogeologic data is very limited for the Rattlesnake, but in general it is known that there is not a lot of water in the Rattlesnake alluvial aquifer. The high average nitrate-N concentration indicates that although the overall sensitivity is lower than other areas, the relatively high total sewage loading in the area is impacting water quality.

Lolo (6th Priority);
Lolo was assigned a final ranking score of 29. There are 456 total units within the Lolo review area, and 419 (92%) are using septic systems. Records indicate there are 13 commercial properties in the Lolo area, and overall, 2.9% of the properties are commercial. For this factor the Lolo area was assigned a relatively high ordinal ranking score of 5. Overall septic system density in the Lolo area was 0.33 units/acre, and for this factor the area was assigned a low ordinal ranking score of 2. The Mullan Road area was the only area with a lower density. There were no quarter sections in the Lolo area that had over 160 units/quarter section.

Based on the 419 unsewered units in the area, Lolo contributes 83,800 gallons/day (30.6 million gallons/year) of sewage and 35 pounds/day (12,775 pounds/year) of total nitrogen to the subsurface. For cumulative impacts/nitrogen loading the Lolo area also received a low ordinal ranking score of 2. The Lolo area also received a low ordinal ranking score of 2 for percentage of seepage pit systems. Based on septic system permit records, only 18 (19%) of the 96 permitted septic systems in the Lolo area use seepage pits.

Approximately 6% of the septic systems in the Lolo area have failed since 1967, and for this factor the area also received a relatively low ordinal ranking score of 3. A total of 25 replacement septic system permits have been issued in the Lolo area.

Current nitrate-N concentrations in groundwater in the Lolo area was based mainly on data from public water supply wells because no access to private wells was obtained within the study area. One monitoring well installed by the Water Quality District was sampled, and data from 10 public water supply wells were obtained. The average nitrate-N concentration was 1.10 mg/l. This level is higher than all other area except Mullan Road and the Rattlesnake Valley. For this factor the Lolo area was assigned an ordinal ranking score of 6.s No bacterial data was available for the Lolo area. Groundwater from the Lolo area flows north, generally following the Bitterroot River valley. Records of drillers logs indicate that there are 121 wells in the Lolo review area, with an overall well density of 61 wells/mile^2. For this factor the area was assigned a low ordinal ranking score of 3. The Lolo area was assigned a relatively high ordinal ranking score of 6 for aquifer vulnerability, based on the DRASTIC analysis.

Mullan Road (7th Priority);
The Mullan Road area had the second lowest overall ranking score, with a final score of 27. Records indicate there are 1017 total units in the Mullan Road area, and of these 627 (62%) use septic systems. The overall density of commercial units in the area is 1.4%, with 14 commercial properties within the review area. For this factor the area was assigned an ordinal ranking score of 4. The Mullan Road area had the lowest overall septic system density at 0.23 units/acre. For this factor the area was assigned the lowest ordinal ranking score of 1.

Based on the 627 unsewered units in the Mullan Road review area, this area contributes 125,400 gallons/day (45.8 million gallons/year) of sewage and 52 pounds/day (18,980 pounds/year) of total nitrogen to the subsurface. For the cumulative impacts/nitrogen loading factor this area was assigned an ordinal ranking score of 4.

Based on septic system permit records, only 16% of the septic systems in the Mullan Road area use seepage pits. Records indicate that 146 septic system permits have been issued in the area, and 24 of those permits were for seepage pits. For percentage of seepage pits the Mullan Road area was assigned the lowest ordinal ranking score of 1. The area also was assigned the lowest ordinal ranking score for percentage of septic systems replaced since 1967, with 4.2% of the systems replaced.

The Mullan Road review area had the second highest overall nitrate-N concentration in groundwater, with an average concentration of 1.18. For this factor the area was assigned the second highest ordinal ranking score of 7. The area contains 10 public water supply wells. This area also had several private wells that showed persistent bacterial contamination. Groundwater from this area generally flows west towards the Clark Fork River.

Records of drillers logs indicate that there are 265 wells within the Mullan Road area, with an overall well density of 62 wells/mile^2. For well density the area was assigned an ordinal ranking score of 4. Aquifer sensitivity in the area was relatively high based on the DRASTIC analysis, and for this factor the area was assigned an ordinal ranking score of 5.

In general, densities in the area are currently low, but future growth potential is high. This area did not contain any quarter sections with a septic system density greater than 160 units/quarter section.

Westview Park (8th Priority);
The Westview Park area ranked lowest overall, with a final ranking score of 23. This area had the most unusual ranking, with all eight factors either ranked very high or very low (see Table 30). Records indicate there 364 units in the area, and all units use septic systems. Only one commercial property is listed in the area, and for this factor the area was assigned the lowest ordinal ranking score of 1.

This area had the highest overall septic system density with 364 unsewered units in one quarter section (2.28 units.acre). The area consists of mobile homes, and in most cases there is one septic system for each two mobile homes. For overall septic system density this area was assigned the highest ordinal ranking score of 8. This area also represents one of the high density quarter sections. It is unique in that it is the only general area that covered only one quarter section. Because the same data was used for ranking the high density quarter sections, the quarter section representing Westview Park also ranked low (13th in priority out of 14 quarter sections).

The Westview Park area also received the lowest ordinal ranking score of 1 for cumulative impacts/nitrogen loading, due to the limited number of units in the area. This area contributes approximately 72,800 gallons/day (26.6 million gallons/year) of sewage and 30 pounds/day (10,950 pounds/year) of total nitrogen to the subsurface. Nitrate-N levels in wells located directly down gradient of this area showed significant impacts, with levels above 2.5 mg/l. Groundwater directly up gradient of this area had nitrate-N levels below 2.5 mg/l.

Almost all septic systems in the Westview Park area use seepage pits. Septic system permit records are lacking for the area, but it in known that in most cases there is one seepage pit for every two mobile homes in the area. For percentage of seepage pits this area was assigned the highest ordinal ranking score of 8. Records of septic system replacement permits indicate that 4.7% of the septic systems in this area have been replaced since 1967. For percentage of replacement septic systems this area was assigned a low ordinal ranking score of 2.

Data on nitrate-N levels in groundwater in the Westview Park area are very limited. Data from only two public water supply wells were obtained, and both wells are located on the up gradient side of the area. Nitrate-N levels in these two wells were low, but private wells immediately down gradient of the Westview Park area, but outside of the review area showed levels above 2.5 mg/l nitrate-N. For this factor this area was assigned the lowest ordinal ranking score of 1, but this does not reflect the measured cumulative impacts to groundwater in this area.

Records of wells only indicate the two public water supply wells, so for well density this area was assigned the lowest ordinal ranking score of 1. The area also was assigned the lowest ordinal ranking score of 1 for aquifer vulnerability, based on the DRASTIC analysis. This low ranking is due to low reported hydraulic conductivity values and greater depth to groundwater. Hydraulic conductivity values used for the DRASTIC analysis in this area are based on hydrogeologic data presented by Pottinger (1988) and Smith (1992). The values used may be lower than the actual values, and additional investigation of the hydrogeology in the area of the Grant Creek alluvial fan is needed.

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APPENDIX A

NITRATE AND BACTERIA SAMPLING RESULTS FOR DOMESTIC WELLS AND MONITORING WELLS

WQD INDIVIDUAL & MONITORING WELL RESULTS

SAMPLE_ID	PROP_N		STREET_NAM	TYPE		NO3_1	BACT_1	NO3_2	BACT_2	NO3_3	BACT_3	NO3_4	BACT_4	BACT	N_MIN	N_MAX	N_AVG
1	1719		RIVER	RD		0.51	<1COL/100ML	0.48	<1COL/100ML	0.59	1COL/100ML	0.51	<1COL/100ML	C	0.48	0.59	0.52
3	1626		PITTMAN	DR		1.29	<1COL/100ML	1.14	<1COL/100ML	1.45	<1COL/100ML	1.44	<1COL/100ML		1.14	1.45	1.33
4	3514		NORMAN	DR		0.84	<1COL/100ML	0.78	<1COL/100ML	0.52	<1COL/100ML	0.85	<1COL/100ML		0.52	0.85	0.75
6	9295		WOODWIND	TRL		0.41	<1COL/100ML	0.43	<1COL/100ML	0.68	<1COL/100ML	0.56	<1COL/100ML		0.41	0.68	0.52
7	9280		KEEGAN TRAIL	RD		0.79	<1COL/100ML	0.03	<1COL/100ML	0.04	<1COL/100ML	0.02	<1COL/100ML		0.02	0.79	0.22
8	365		BLUE HERON	LA		0.27	<1COL/100ML	0.26	<1COL/100ML	0.26	<1COL/100ML	0.21	<1COL/100ML		0.21	0.27	0.25
9	1401		CLEMENTS	RD		0.93	<1COL/100ML	0.90	TNTCW	1.02	<1COL/100ML	0.88	TNTCWO	C	0.88	1.02	0.93
10	3205	S	07TH	ST	W	0.67	<1COL/100ML	0.49	<1COL/100ML	0.93	<1COL/100ML	0.81	<1COL/100ML		0.49	0.93	0.73
11	600		RIVER	CT		0.54	<1COL/100ML	0.52	<1COL/100ML	0.57	<1COL/100ML	0.52	<1COL/100ML		0.52	0.57	0.54
13	1103		CREEK CROSSING ROAD			3.82	<1COL/100ML	2.97	<1COL/100ML	2.90	<1COL/100ML	3.79	<1COL/100ML		2.90	3.82	3.37
15	1050		COUNCIL	WY		0.51	<1COL/100ML	0.49	TNTCWO	0.54	<1COL/100ML	0.48	<1COL/100ML	N	0.48	0.54	0.51
16	2603		LAURIE	DR		0.52	<1COL/100ML	0.78	TNTCW	0.65	<1COL/100ML	0.63	4COL/100ML	C	0.52	0.78	0.65
18	4803		HANSON	DR		1.00	<1COL/100ML	0.97	<1COL/100ML	0.97	<1COL/100ML	1.01	<1COL/100ML		0.97	1.01	0.99
19	3239	S	03RD	ST		0.97	<1COL/100ML	0.52	TNTCW (71COL/10	1.09	2COL/100ML	0.24	<1COL/100ML	C	0.24	1.09	0.71
20	4612		NORTH	AV	W	1.51	<1COL/100ML	1.11	<1COL/100ML	1.14	TNTCW	1.13	<1COL/100ML	C	1.11	1.51	1.22
22	4650		US HWY 200		E	0.38	<1COL/100ML	0.44	<1COL/100ML	0.38	<1COL/100ML	0.36	<1COL/100ML		0.36	0.44	0.39
23	4421		EDWARD	ST		1.04	<1COL/100ML	1.05	<1COL/100ML	1.03	<1COL/100ML	1.08	<1COL/100ML		1.03	1.08	1.05
25	908		GLADIS	DR		0.77	<1COL/100ML	0.43	<1COL/100ML	0.85	<1COL/100ML	0.78	<1COL/100ML		0.43	0.85	0.71
26	3615		RATTLESNAKE	DR		0.79	<1COL/100ML	0.84	<1COL/100ML	0.81	<1COL/100ML	0.81	<1COL/100ML		0.79	0.84	0.81
28	1475		CREST HAVEN	DR		0.79	<1COL/100ML	0.75	<1COL/100ML	0.76	<1COL/100ML	0.81	<1COL/100ML		0.75	0.81	0.78
29	3250		PATTEE CANYON	RD		0.31	<1COL/100ML	0.30	<1COL/100ML	0.32	<1COL/100ML	0.32	<1COL/100ML		0.30	0.32	0.31
31	3311	S	07TH	ST	W	0.66	<1COL/100ML	0.59	TNTCWO (<1COL/1	0.75	<1COL/100ML	0.76	TNTCWO	N	0.59	0.76	0.69
32	728	N	DAVIS	ST		0.24	<1COL/100ML	0.36	<1COL/100ML	0.37	<1COL/100ML	0.26	<1COL/100ML		0.24	0.37	0.31
36	1575		TOPAZ	DR		1.16	TNTCWO	1.06	TNTCW (TNTCW)10	1.15	1COL/100ML	1.28	TNTCWO	C	1.06	1.28	1.16
37	4701		COUNTRY CLUB	LA		3.12		3.16	15COL/100ML	3.40	<1COL/100ML	3.24	<1COL/100ML	C	3.12	3.40	3.23
38	245	N	DAVIS	ST		0.64	<1COL/100ML	0.57	<1COL/100ML	0.70	<1COL/100ML	0.63	<1COL/100ML		0.57	0.70	0.64
39	3660		MULLAN	RD		0.90	<1COL/100ML	0.00		1.19	<1COL/100ML	1.16	<1COL/100ML		0.90	1.19	1.08
40	2985		BIG FLAT	RD		1.07	<1COL/100ML	0.94	<1COL/100ML	1.26	<1COL/100ML	1.12	<1COL/100ML		0.94	1.26	1.10
41	1025		LOST MINE LOOP			0.30	<1COL/100ML	0.29	<1COL/100ML	0.00		0.32	<1COL/100ML		0.29	0.32	0.30
42	2390		CLYDESDALE			0.47	<1COL/100ML	0.48	<1COL/100ML	0.73	<1COL/100ML	0.57	<1COL/100ML		0.47	0.73	0.56
43	2300		RATTLESNAKE	DR		3.00	<1COL/100ML	2.23	<1COL/100ML	1.79	<1COL/100ML	2.45	<1COL/100ML		1.79	3.00	2.37
44	2307		PAULINE	DR		1.15	<1COL/100ML	1.11	<1COL/100ML	1.02	111COL/100ML	1.09	<1COL/100ML	C	1.02	1.15	1.09
47	4050		HWY 10		W	0.00		0.00		3.86	<1COL/100ML	3.39	<1COL/100ML		3.39	3.86	3.63
48	212		TOWER	ST		0.25	<1COL/100ML	0.27	<1COL/100ML	0.25	<1COL/100ML	0.28	<1COL/100ML		0.25	0.28	0.26
49	1475		EATON	ST		0.59	TNTCWO	0.81	TNTCWO (TNTCWO)	0.76	5COL/100ML	0.60	TNTCWO	C	0.59	0.81	0.69
50	2990		WOODLAND	DR		0.00		0.00		0.22	<1COL/100ML	0.00			0.22	0.22	0.22
52	431		MONTANA	AV		0.51	<1COL/100ML	0.39	<1COL/100ML	0.37	<1COL/100ML	0.58	<1COL/100ML		0.37	0.58	0.46
53	9320		WESTERN FARMS	RD		0.53	<1COL/100ML	0.51	<1COL/100ML	0.00		0.00			0.51	0.53	0.52

WQD INDIVIDUAL & MONITORING WELL RESULTS

SAMPLE_ID	PROP_N		STREET_NAM	TYPE		NO3_1	BACT_1	NO3_2	BACT_2	NO3_3	BACT_3	NO3_4	BACT_4	BACT	N_MIN	N_MAX	N_AVG
54	1409		WOODLAWN	ST		1.00	<1COL/100ML	1.00	<1COL/100ML	0.95	<1COL/100ML	1.02	<1COL/100ML		0.95	1.02	0.99
55	2722	S	07TH	ST	W	0.66	<1COL/100ML	0.00	TNTCWO (<1COL/1	0.77	<1COL/100ML	0.73	<1COL/100ML	N	0.66	0.77	0.72
56	2731		ANCABIDE	LA		2.28	<1COL/100ML	2.02	<1COL/100ML	2.45	<1COL/100ML	2.36	<1COL/100ML		2.02	2.45	2.28
57	3825	W	CENTRAL	AV		1.32	<1COL/100ML	1.04	<1COL/100ML	1.24	<1COL/100ML	1.24	<1COL/100ML		1.04	1.32	1.21
58	3001		TINA	DR		0.56	<1COL/100ML	0.68	<1COL/100ML	0.23	<1COL/100ML	0.39	<1COL/100ML		0.23	0.68	0.47
60	4722		ASPEN	DR		0.54	<1COL/100ML	0.01	TNTCW (<1COL/10	0.87	11COL/100ML (FE	1.15	<1COL/100ML	F	0.01	1.15	0.64
61	2211		27TH	AV		0.97	<1COL/100ML	1.08	<1COL/100ML	1.31	<1COL/100ML	1.07	<1COL/100ML		0.97	1.31	1.11
62	1640		MONTANA	ST		0.51	<1COL/100ML	0.44	<1COL/100ML	0.58	<1COL/100ML	0.51	<1COL/100ML		0.44	0.58	0.51
63	1521		CLEMENTS	RD		0.85	<1COL/100ML	0.87	<1COL/100ML	0.99	<1COL/100ML	0.83	<1COL/100ML		0.83	0.99	0.89
68	1425		THIBODEAU	LA		0.48	<1COL/100ML	0.54	<1COL/100ML	0.44	<1COL/100ML	0.46	<1COL/100ML		0.44	0.54	0.48
69	4980		LOWER MILLER CREEK	RD		0.60	<1COL/100ML	0.60	<1COL/100ML	0.62	<1COL/100ML	0.62	<1COL/100ML		0.60	0.62	0.61
70	7815		FLAGLER	RD		0.54	<1COL/100ML	0.38	<1COL/100ML	0.31	<1COL/100ML	0.32	<1COL/100ML		0.31	0.54	0.39
71	8140		FLAGLER	RD		0.32	<1COL/100ML	0.30	<1COL/100ML	0.29	<1COL/100ML	0.31	<1COL/100ML		0.29	0.32	0.31
72	4765		ARNICA			0.49	<1COL/100ML	0.42	<1COL/100ML	0.42	<1COL/100ML	0.46	<1COL/100ML		0.42	0.49	0.45
74	615		PATTEE CANYON	RD		0.94	5COL/100ML	1.10	<1COL/100ML	1.00	<1COL/100ML	0.46	<1COL/100ML	C	0.46	1.10	0.88
76	2929		MABELLE	LA		1.44	<1COL/100ML	1.58	9COL/100ML (76C	1.48	<1COL/100ML	1.43	<1COL/100ML	C	1.43	1.58	1.48
77	1315		RIVER	RD		0.61	<1COL/100ML	0.61	<1COL/100ML	0.54	<1COL/100ML	0.00	<1COL/100ML		0.54	0.61	0.59
78	2825		ST MICHAEL	DR		0.02	<1COL/100ML	0.01	<1COL/100ML	0.00		0.01	<1COL/100ML		0.01	0.02	0.01
79	15720		MULLAN	RD		0.00		0.00		0.79	<1COL/100ML	0.97	<1COL/100ML		0.79	0.97	0.88
82	1705		TOPAZ	DR		1.19	TNTCWO (<1COL/1	1.07	<1COL/100ML	1.16	<1COL/100ML	1.19	TNTCWO	N	1.07	1.19	1.15
83	2816		SOUTH	AV	W	1.17	<1COL/100ML	1.34	<1COL/100ML	1.55	<1COL/100ML	1.34	<1COL/100ML		1.17	1.55	1.35
84	1203		VAN BUREN	ST		1.22	<1COL/100ML	0.83	2COL/100ML	0.00		0.79	<1COL/100ML	C	0.79	1.22	0.95
85	2200		APPLEWOOD	LA		0.61	<1COL/100ML	0.61	<1COL/100ML	0.58	<1COL/100ML	0.57	<1COL/100ML		0.57	0.61	0.59
88	4640		ZINTEK	PL		1.70	<1COL/100ML	1.31	<1COL/100ML	1.43	<1COL/100ML	1.90	<1COL/100ML		1.31	1.90	1.59
90	5055		FOREST HILL	LA		2.81	<1COL/100ML	1.84	<1COL/100ML	2.50	<1COL/100ML	2.12	<1COL/100ML		1.84	2.81	2.32
91	3840		MOUNT	ST		0.95	2COL/100ML	0.00		0.93	<1COL/100ML	0.89	<1COL/100ML	C	0.89	0.95	0.92
92	1517		37TH	AV		0.92	<1COL/100ML	0.00		0.91	<1COL/100ML	0.94	<1COL/100ML		0.91	0.94	0.92
93	931		GLADIS	DR		0.68	<1COL/100ML	0.41	<1COL/100ML	0.75	<1COL/100ML	0.84	<1COL/100ML		0.41	0.84	0.67
95	4025		RODEO NEWS	WY		0.17	TNTCW-NF	0.29	<1COL/100ML	0.00		0.11	128COL/100ML	C	0.11	0.29	0.19
96	14100		HARPER BRIDGE	RD		0.68	<1COL/100ML	0.29	<1COL/100ML	0.46	<1COL/100ML	0.68	<1COL/100ML		0.29	0.68	0.53
97	1025	S	RESERVE	ST		0.94	<1COL/100ML	0.88	<1COL/100ML	0.82	<1COL/100ML	0.97	<1COL/100ML		0.82	0.97	0.90
98	806		GARY	DR		0.59	<1COL/100ML	0.76	<1COL/100ML	0.78	<1COL/100ML	0.66	<1COL/100ML		0.59	0.78	0.70
99	2835		LORRAINE	DR		0.02	<1COL/100ML	0.01	<1COL/100ML	0.01	<1COL/100ML	0.01	<1COL/100ML		0.01	0.02	0.01
100	3900		SOUTH	AV	W	1.00	<1COL/100ML	0.89	<1COL/100ML	0.92	<1COL/100ML	0.96	<1COL/100ML		0.89	1.00	0.94
101	3010		TINA	DR		1.03	<1COL/100ML	0.80	<1COL/100ML	0.21	<1COL/100ML	0.66	<1COL/100ML		0.21	1.03	0.68
102	1065		HAAGLUND	DR		0.09	<1COL/100ML	0.07	<1COL/100ML	0.03	<1COL/100ML	0.00	<1COL/100ML		0.03	0.09	0.06
103	1826		MONTANA	ST		0.68	TNTCWO (TNTCW)7	0.53	TNTCW (TNTCW)10	0.56	TNTCW	0.50	TNTCW	C	0.50	0.68	0.57
104	8300		O'BRIEN CREEK	RD		0.49	<1COL/100ML	1.42	<1COL/100ML	0.56	<1COL/100ML	0.54	<1COL/100ML		0.49	1.42	0.75

WQD INDIVIDUAL & MONITORING WELL RESULTS

SAMPLE_ID	PROP_N		STREET_NAM	TYPE		NO3_1	BACT_1	NO3_2	BACT_2	NO3_3	BACT_3	NO3_4	BACT_4	BACT	N_MIN	N_MAX	N_AVG
106	1232		ROSEBRIER	DR		0.88	<1COL/100ML	1.00	<1COL/100ML	0.66	<1COL/100ML	0.77	<1COL/100ML		0.66	1.00	0.83
111	3810	S	07TH	ST	W	0.79	29COL/100ML	0.77	TNTCW (<1COL/10	0.73	<1COL/100ML	0.74	<1COL/100ML	C	0.73	0.79	0.76
114	3426		SOUTH	AV	W	0.93	<1COL/100ML	0.98	<1COL/100ML	0.95	<1COL/100ML	0.96	<1COL/100ML		0.93	0.98	0.96
115	1650		HAYES	DR		1.10	TNTCWO	1.04	<1COL/100ML	1.19	<1COL/100ML	1.16	<1COL/100ML	N	1.04	1.19	1.12
116	4855		DEER CREEK	RD		0.26	<1COL/100ML	0.31	<1COL/100ML	0.26	<1COL/100ML	0.23	<1COL/100ML		0.23	0.31	0.27
120	2316		PAULINE	DR		1.01	<1COL/100ML	1.02	<1COL/100ML	0.97	<1COL/100ML	0.97	<1COL/100ML		0.97	1.02	0.99
122	600		CITY	DR		0.87	<1COL/100ML	0.95	<1COL/100ML	0.64	<1COL/100ML	0.69	<1COL/100ML		0.64	0.95	0.79
123	210		SHORT			0.43	<1COL/100ML	0.68	<1COL/100ML	0.48	<1COL/100ML	0.33	<1COL/100ML		0.33	0.68	0.48
124	2740	S	03RD	ST	W	0.56	<1COL/100ML	0.00		0.61	<1COL/100ML	0.00			0.56	0.61	0.59
130	4741		SUNDOWN	RD		0.26	<1COL/100ML	0.27	<1COL/100ML	0.24	<1COL/100ML	0.25	<1COL/100ML		0.24	0.27	0.26
131	2540	S	07TH	ST	W	0.72	TNTCWO	1.06	TNTCWO (7COL/10	0.80	<1COL/100ML	0.71	<1COL/100ML	C	0.71	1.06	0.82
132	2515		SUNSET	LN		0.78	<1COL/100ML	0.78	TNTCWO (<1COL/1	0.71	<1COL/100ML	0.81	<1COL/100ML	N	0.71	0.81	0.77
133	2122		RIVER	RD		0.35	<1COL/100ML	0.48	<1COL/100ML	0.50	<1COL/100ML	0.44	<1COL/100ML		0.35	0.50	0.44
134	4810		MILLER CREEK	RD		2.58	<1COL/100ML	2.59	TNTCWO (1COL/10	2.89	TNTCWO	5.50	<1COL/100ML	C	2.58	5.50	3.39
135	9855		GRANT CREEK	RD		0.23	<1COL/100ML	0.65	<1COL/100ML	0.17	<1COL/100ML	0.24	<1COL/100ML		0.17	0.65	0.32
136	2512		OLOFSON	DR		0.79	<1COL/100ML	0.77	<1COL/100ML	0.79	<1COL/100ML	0.67	<1COL/100ML		0.67	0.79	0.76
137	2624		SPURGIN	RD		0.91	<1COL/100ML	0.85	<1COL/100ML	0.95	<1COL/100ML	0.96	<1COL/100ML		0.85	0.96	0.92
138			DUNN	LN		0.87	<1COL/100ML	0.00		0.88	<1COL/100ML	0.82	<1COL/100ML		0.82	0.88	0.86
139	203	N	GROVE			0.57	3COL/100ML (<1C	0.90	5COL/100ML (37C	0.52	3COL/100ML	0.54	<1COL/100ML	C	0.52	0.90	0.63
140	2835		STRAND			0.82	<1COL/100ML	0.85	<1COL/100ML	0.87	<1COL/100ML	0.85	<1COL/100ML		0.82	0.87	0.85
141	116		RIVER PINES	RD		0.53	<1COL/100ML	0.85	<1COL/100ML	0.84	<1COL/100ML	0.00			0.53	0.85	0.74
142	2522		STRAND			0.54	<1COL/100ML	0.78	<1COL/100ML	0.60	<1COL/100ML	0.61	<1COL/100ML		0.54	0.78	0.63
145	400	W	ARTEMOS	DR		1.89	TNTCW	1.15	<1COL/100ML	1.31	<1COL/100ML	0.90	<1COL/100ML	C	0.90	1.89	1.31
146	2930		SPURGIN	RD		0.79	<1COL/100ML	0.53	<1COL/100ML	0.95	<1COL/100ML	0.90	<1COL/100ML		0.53	0.95	0.79
147	1200		TULIP	LN		1.30	<1COL/100ML	1.03	<1COL/100ML	0.80	<1COL/100ML	1.01	<1COL/100ML		0.80	1.30	1.04
148	705		GARY	DR		0.56	<1COL/100ML	0.00		0.70	<1COL/100ML	0.66	<1COL/100ML		0.56	0.70	0.64
149	5120		HUCKLEBERRY	RD		0.21	<1COL/100ML	0.20	<1COL/100ML	0.00		0.22	<1COL/100ML		0.20	0.22	0.21
151	1910		29TH	ST		0.88	<1COL/100ML	0.94	<1COL/100ML	0.99	<1COL/100ML	1.02	<1COL/100ML		0.88	1.02	0.96
153	2140		GREENOUGH	DR		0.80	<1COL/100ML	0.94	<1COL/100ML	0.64	<1COL/100ML	0.41	<1COL/100ML		0.41	0.94	0.70
154	3020		BRIGGS	ST		1.35	<1COL/100ML	1.46	<1COL/100ML	1.46	<1COL/100ML	1.33	<1COL/100ML		1.33	1.46	1.40
155	1244		MONTANA	ST		0.54	<1COL/100ML	0.00	<1COL/100ML	0.59	<1COL/100ML	0.54	<1COL/100ML		0.54	0.59	0.56
157	3116		MARTINWOOD	RD		0.53	<1COL/100ML	0.00		0.00		1.97	<1COL/100ML		0.53	1.97	1.25
158	10742		ORAL ZUMWALT	WAY		0.00		1.02	<1COL/100ML	0.00		0.52	<1COL/100ML		0.52	1.02	0.77
159	4526		RIO VISTA	DR		1.33	<1COL/100ML	1.13	<1COL/100ML	1.35	<1COL/100ML	1.46	<1COL/100ML		1.13	1.46	1.32
161	1710		LENORE	CT		0.78	<1COL/100ML	0.81	<1COL/100ML	0.92	<1COL/100ML	0.75	<1COL/100ML		0.75	0.92	0.82
163	916		GLADIS	DR		0.62	<1COL/100ML	0.21	<1COL/100ML	0.73	<1COL/100ML	0.82	<1COL/100ML		0.21	0.82	0.60
164	5050		HUCKLEBERRY	RD		0.23	<1COL/100ML	0.21	<1COL/100ML	0.22	<1COL/100ML	0.24	<1COL/100ML		0.21	0.24	0.23
165	6020	E	RATTLESNAKE	DR		0.24	<1COL/100ML	0.12	<1COL/100ML	0.09	<1COL/100ML	0.08	<1COL/100ML		0.08	0.24	0.13

WQD INDIVIDUAL & MONITORING WELL RESULTS

SAMPLE_ID	PROP_N		STREET_NAM	TYPE		NO3_1	BACT_1	NO3_2	BACT_2	NO3_3	BACT_3	NO3_4	BACT_4	BACT	N_MIN	N_MAX	N_AVG
166	2024	W	GREENOUGH	DR		1.69	<1COL/100ML	1.02	<1COL/100ML	0.82	<1COL/100ML	1.06	<1COL/100ML		0.82	1.69	1.15
167	5120		LARCH	LN		0.07	<1COL/100ML	0.14	<1COL/100ML	0.18	<1COL/100ML	0.39	<1COL/100ML		0.07	0.39	0.20
168	1603		ALTURA	DR		1.44	<1COL/100ML	1.86	<1COL/100ML	1.73	<1COL/100ML	1.87	<1COL/100ML		1.44	1.87	1.73
169	4235		SUNDOWN	RD		1.18	<1COL/100ML	1.90	TNTCW (<1COL/10	1.25	<1COL/100ML	1.24	<1COL/100ML	C	1.18	1.90	1.39
170	4303		EDWARD			0.95	<1COL/100ML	0.92	<1COL/100ML	0.87	<1COL/100ML	0.95	1COL/100	C	0.87	0.95	0.92
171	4607		NORTH	AV	W	1.05	<1COL/100ML	1.41	<1COL/100ML	1.25	<1COL/100ML	1.42	<1COL/100ML		1.05	1.42	1.28
172	2105		DEARBORN	ST		0.89	<1COL/100ML	0.67	<1COL/100ML	0.66	<1COL/100ML	0.51	<1COL/100ML		0.51	0.89	0.68
173	3212		HELENA	DR		9.20	<1COL/100ML	9.36	<1COL/100ML	10.10	<1COL/100ML	10.20	<1COL/100ML		9.20	10.20	9.72
180	407	N	CALIFORNIA	ST		0.62	<1COL/100ML	0.62	<1COL/100ML	0.64	<1COL/100ML	0.65	<1COL/100ML		0.62	0.65	0.63
181	1240		WYOMING	ST		0.43	<1COL/100ML	0.46	<1COL/100ML	0.47	<1COL/100ML	0.47	<1COL/100ML		0.43	0.47	0.46
182	400	N	CALIFORNIA	ST		0.63	<1COL/100ML	0.00		0.64	<1COL/100ML	0.55	<1COL/100ML		0.55	0.64	0.61
185	300	N	RUSSELL	ST		0.55	<1COL/100ML	0.57	<1COL/100ML	0.57	<1COL/100ML	0.55	<1COL/100ML		0.55	0.57	0.56
186	1309		IDAHO	ST		0.56	<1COL/100ML	0.57	<1COL/100ML	0.63	<1COL/100ML	0.60	<1COL/100ML		0.56	0.63	0.59
190	1270	S	01ST	ST	W	0.42	<1COL/100ML	0.46	TNTCW (<1COL/10	0.48	1COL/100ML	0.45	<1COL/100ML	C	0.42	0.48	0.45
191	210	N	CALIFORNIA	ST		0.68	<1COL/100ML	0.47	<1COL/100ML	0.58	<1COL/100ML	0.60	<1COL/100ML		0.47	0.68	0.58
192	1224		MONTANA	ST		0.55	<1COL/100ML	0.54	<1COL/100ML	0.61	<1COL/100ML	0.57	<1COL/100ML		0.54	0.61	0.57
193	1330		MONTANA	ST		0.51	<1COL/100ML	0.50	<1COL/100ML	0.51	<1COL/100ML	0.52	<1COL/100ML		0.50	0.52	0.51
194	1332		MONTANA	ST		0.49	<1COL/100ML	0.52	<1COL/100ML	0.54	<1COL/100ML	0.52	<1COL/100ML		0.49	0.54	0.52
195			TOWER	ST		0.13		0.00		0.98		1.00			0.13	1.00	0.70
196			VINE	ST		0.84		0.00		0.90		0.00			0.84	0.90	0.87
197			BLAINE	ST		0.58		0.00		0.37		0.70			0.37	0.70	0.55
198			SOUTH	AV		2.34		0.00		1.02		2.50			1.02	2.50	1.95
201	1810		RIVERSIDE	DR		0.00		0.84	<1COL/100ML	0.83	<1COL/100ML	0.00	<1COL/100ML		0.83	0.84	0.84
202	1500		39TH	ST		0.00		0.00		1.40	<1COL/100ML	1.52	<1COL/100ML		1.40	1.52	1.46
203	11990		MULLAN	RD		0.00		0.00		0.27	<1COL/100ML	0.34	<1COL/100ML		0.27	0.34	0.31
204	7780		RIVERSIDE	DR		0.00		0.00		0.27		0.17	<1COL/100ML		0.17	0.27	0.22
205	3132		PATTEE CANYON	DR		0.00		0.00		0.00	<1COL/100ML	0.27	<1COL/100ML		0.27	0.27	0.27
206	4685		EXPRESSWAY			0.00		0.00		0.00		3.00	<1COL/100ML		3.00	3.00	3.00
207	4405		HWY 10		W	0.00		0.00		0.00		2.61	<1COL/100ML		2.61	2.61	2.61
208	280		HELLGATE	DR		0.00		0.00		0.00		0.75	<1COL/100ML		0.75	0.75	0.75
209	4355		HWY 10		W	0.00		0.00		0.00		0.74	<1COL/100ML		0.74	0.74	0.74
210	4801		SUNDOWN	RD		0.00		0.00		0.00		0.76	<1COL/100ML		0.76	0.76	0.76
211	4400		SPURGIN	RD		0.00		0.00		0.00		0.80	<1COL/100ML		0.80	0.80	0.80
212			MADISON	ST		0.00		0.00		0.00		0.60			0.60	0.60	0.60
213			SOUTH	AV		0.00		0.00		0.00		0.90			0.90	0.90	0.90
214			DEER CREEK	RD		0.00		0.00		0.00		0.90			0.90	0.90	0.90
215			HWY 10		E	0.00		0.00		0.00		0.40			0.40	0.40	0.40
216			COLORADO	ST		0.00		0.00		0.00		1.80			1.80	1.80	1.80

WQD INDIVIDUAL & MONITORING WELL RESULTS

	STREET_NAM	TYPE		NO3_1	BACT_1	NO3_2	BACT_2	NO3_3	BACT_3	NO3_4	BACT_4	BACT	N_MIN	N_MAX	N_AVG
	HWY 10		E	0.00		0.00		0.00		0.40			0.40	0.40	0.40
	HWY 93		S	0.00		0.00		0.00		2.00			2.00	2.00	2.00
	MICHAEL	LN		0.00		0.00		0.00		0.50			0.50	0.50	0.50
	FLYNN	LN		0.00		0.00		0.00		0.70			0.70	0.70	0.70
	GREAT WESTERN	AV		0.00		0.00		0.00		2.30			2.30	2.30	2.30
	ALVINA	DR		0.00		0.00		0.00		2.90			2.90	2.90	2.90
S	3RD	ST	W	0.00		0.00		0.00		0.70			0.70	0.70	0.70
	CURTIS	ST		0.00		0.00		0.00		0.90			0.90	0.90	0.90
	CENTRAL	ST	W	0.00		0.00		0.00		2.00			2.00	2.00	2.00
	POST SIDING	RD		0.00		0.00		0.00		1.70			1.70	1.70	1.70
	KONA RANCH	RD		0.00		0.00		0.00		0.80			0.80	0.80	0.80
	TOPAZ	DR		0.00		0.00		0.00		1.30			1.30	1.30	1.30
	MOUNT	ST	W	0.00		0.00		0.00		1.70			1.70	1.70	1.70
	TOUCHETTE	LN		0.00		0.00		0.00		1.20			1.20	1.20	1.20
	ELDORA	LN		8.40	<1COL/100ML	6.16	<1COL/100ML	6.14	<1COL/100ML	9.60	<1COL/100ML		6.14	9.60	7.58
	ELDORA	LN		5.84	<1COL/100ML	6.26	<1COL/100ML	6.72	<1COL/100ML	6.80	<1COL/100ML		5.84	6.80	6.41
	ELDORA	LN		4.07	<1COL/100ML	5.05	<1COL/100ML	6.49	<1COL/100ML	4.20	<1COL/100ML		4.07	6.49	4.95
	ELDORA	LN		6.91	<1COL/100ML	7.21	<1COL/100ML	8.05	<1COL/100ML	8.50	<1COL/100ML		6.91	8.50	7.67
	HELENA	DR		9.20	<1COL/100ML	9.71	<1COL/100ML	10.40	<1COL/100ML	9.80	<1COL/100ML		9.20	10.40	9.78
	HELENA	DR		10.60	<1COL/100ML	11.60	<1COL/100ML	12.30	<1COL/100ML	13.50	<1COL/100ML		10.60	13.50	12.00
	HELENA	DR		11.10	<1COL/100ML	11.80	<1COL/100ML	11.70	<1COL/100ML	12.40	2COL/100ML	C	11.10	12.40	11.75
	HELENA	DR		8.07	<1COL/100ML	0.00		0.00		8.80	<1COL/100ML		8.07	8.80	8.44
	HELENA	DR		5.58	<1COL/100ML	5.25	<1COL/100ML	5.51	<1COL/100ML	5.80	<1COL/100ML		5.25	5.80	5.54
	JAY	LN		4.20	<1COL/100ML	4.68	<1COL/100ML	6.32	<1COL/100ML	2.90	<1COL/100ML		2.90	6.32	4.53

APPENDIX B

LATEST NITRATE RESULTS
FOR
PUBLIC WATER SUPPLY WELLS

LATEST MOUNTAIN WATER NITRATE DATA

DATE	MWC ID	NO 3
4/12/95	01	0.40
1/12/95	02	0.56
3/22/95	03	0.72
8/01/94	04	0.42
8/16/94	08	0.64
3/15/95	09	0.80
4/12/95	10	0.56
3/22/95	11	1.66
8/01/94	12	0.42
3/22/95	14	1.96
6/23/95	16	1.07
8/1/94	17	0.98
8/16/95	18	1.03
3/15/95	19	1.13
3/15/95	20	0.43
4/12/95	21	0.60
4/12/95	22	0.55
3/23/95	23	1.38
3/23/95	24	1.47
3/22/95	25	0.60
3/15/95	26	0.56
3/22/95	27	1.30
4/18/95	28	0.54
3/22/95	29	1.03
3/15/95	30	0.71
4/12/95	31	0.48
3/15/95	32	0.37
4/11/95	33	0.43
4/11/95	34	0.36
4/11/95	35	0.55
3/28/95	36	0.85
3/15/95	37	1.17
3/15/95	38	1.26
9/1/93	3B	0.93

PUBLIC WATER SUPPLY NITRATE DATA

PWS ID	PWS NAME	SAMP DATE	BDL	NO3 N
278	LOLO WATER & SEWER	06/03/91		0.28
327	SEELEY LAKE WATER DISTRICT	11/08/94		0.01
367	TARGET RANGE TRAILER COURT	06/12/92		0.87
368	TAMARACK COURT	11/28/94		0.39
369	RIVER ROAD TRAILER COURT	02/05/91		0.38
370	LEWIS & CLARK TR CT - CLINTON	12/15/94		0.25
372	GREENLAND MOBILE HOME PARK	05/21/92		1.02
373	GREENFIELD MOBILE HOME PARK	06/09/92		1.19
374	FUTURA TRAILER PARK	04/06/92		0.51
376	COUNTRY SIDE COURT – MISSOULA	01/28/92		1.78
377	WEST RIVERSIDE TRAILER COURT	05/13/92		0.21
378	BUENA VISTA TR CT - MISSOULA	02/13/92		0.50
379	WAGON WHEEL TRAILER VILLAGE	06/30/92		0.47
381	BLUE MOUNTAIN TRIALER CT - LOLO	01/28/92		0.35
399	WILDERNESS VILLAGE RESORT	05/19/92		0.30
404	VALLEY VIEW TR CT - FRENCHTOWN	02/04/92		0.64
405	GLESSNER TRAILER COURT	05/14/92		1.03
434	COZY COURT - LOLO	03/27/95		0.50
436	GRASS VALLEY TRAILER COURT	05/24/94		2.00
437	WESTVIEW MOBILE HOME PARK	06/20/94	<	0.05
443	BITTERROOT GATEWAY MB PK - LOLO	03/10/86		0.33
444	VALLEY WEST TRAILER COURT	03/17/94		4.34
449	GREENWOOD TRIALER COURT	06/07/94		0.41
450	BIG PINES MOBILE COURT	12/10/91		0.25
451	CAROLS TRAILER COURT - MILLTOWN	05/19/92		0.19
452	CIRCLE J TRAILER COURT	09/07/93		0.36
453	HARVEYS MOBILE HOME COURT	05/13/92		0.10
454	HOLLYWOOD MOBILE HOME COURT	06/23/92		1.21
455	MOUNTAIN VIEW TR CT - MISSOULA	09/30/93		1.21
467	STIMSON LUMBER CO – BONNER MILL	02/20/84		0.09
489	TWO RIVERS MOBILE HM PK – LOLO	06/30/92		0.14
490	VALLEY GROVE WUA – LOLO	12/20/93		4.09
492	NINE MILE HOUSE & TRLR CT	12/27/94		0.02
517	EL MAR ESTATES W & S – MSLA CO	02/04/92		1.16
518	SORREL SPRINGS HOA	06/10/92		0.07
575	RAMER WATER SUPPLY	02/05/91		0.66
630	TANDYS RENO INN AND TR CT	06/25/92		2.64
632	ELK MEADOWS RANCHETTES	03/20/89		0.39
646	MOBILE CITY TRAILER COURT	06/16/92		0.05
799	ROCK CREEK LODGE	11/28/94		0.25
800	SIX MILE TAVERN	04/01/92		0.40
803	LUMBERJACK SALOON	06/26/92		0.10
804	LOLO TAVERN – LOLO	02/11/91		0.30
805	LOLO HOT SPRINGS INC	09/06/88		0.10
808	KT'S HAYLOFT SALOON	02/11/91		0.30
809	EKSTROMS STAGE STATION	05/30/92		0.10
812	ALCAN BAR & CAFE	11/30/94		0.77
813	WAY WEST LOUNGE	11/07/94		3.14
815	TWO BEARS TRUCK STOP	11/30/88		0.30
816	CLEARWATER SUPPLY STONEY'S 4-G	06/01/89		0.30
817	BALCKFOOT TAVERN – BONNER	02/01/90		0.10
820	GO WEST DRIVE IN THEATER	10/05/93		1.86
822	WATKINS INC – 93 STOP 'N GO	01/24/91		0.80

PUBLIC WATER SUPPLY NITRATE DATA

PWS ID	PWS NAME	SAMP DATE	BDL	NO3 N
824	CLINTON SCHOOL	12/19/94		0.48
825	JOHN R DAILY INC	12/20/94		0.79
828	IMPERIAL FOODS 4B'S WHOLESALE	02/13/92		0.30
829	2727 WEST CENTRAL DUPLEXES	06/29/92		0.91
832	FORT FIZZLE INN	06/26/92		0.20
834	MARVINS BAR	03/25/92		0.50
836	OUT POST CAMPGROUND	05/12/92		0.40
837	LOUISIANA PACIFIC CORPORATION	12/29/94		0.66
838	TARGET RANGE LITTLE SCHOOL	01/24/91		1.00
839	STONE CONTAINER CORPORATION	06/15/92		0.40
840	FOREST INN LOUNGE & APARTMENTS	02/13/92		0.13
841	HOLLAND LAKE LODGE	03/10/88		3.10
842	DESMET PUBLIC SCHOOL	01/28/92		2.00
843	TURAH PINES BAR	05/19/89		0.90
844	SNOWBOWL LODGE	12/01/88		0.40
845	HELLGATE ELEMENTARY SCHOOL #1	01/28/92		0.90
846	BONNER SCHOOL DISTRICT #14	02/12/91		0.30
847	MURALTS PLAZA CAFE	11/07/94		1.69
849	POTOMAC COUNTRY STORE & BAR	02/06/90		0.60
850	LIQUID LOUIE'S BAR	03/20/90		4.00
851	CROSSROADS TRUCK CENTER	11/08/94		1.00
852	POOR HENRYS BAR & CAFE & TR CT	11/28/94		0.96
855	POTOMAC SCHOOL LOWER WELL #1	02/19/91		0.80
856	FRENCHTOWN HIGH SCHOOL	07/03/91		0.91
860	DOUBLE ARROW LODGE	02/12/91		0.40
861	TURAH STORE AND CAMPGROUND	03/30/93		0.31
866	KOZY KORNER STEAKHOUSE & BAR	04/19/90		1.30
867	LUBRECHT EXPERIMENTAL FOREST	06/30/88		0.20
870	NASH FAMILY RENTALS	06/23/92		1.34
873	HUNGRY BEAR STEAKHOUSE	02/06/90		0.10
1855	EVARO BAR	11/14/94		0.06
1857	SUNSET WEST HOA – FRENCHTOWN	04/05/90		1.98
1864	SUNNY MEADOWS SUBDIVISION	09/06/94		0.50
1865	WHITE WATER PARK ASSOC – BONNER	08/24/92		1.44
1867	CABIN COMPLEX	05/11/89		1.40
1869	ELK HORN GUEST RANCH	05/30/92		0.20
1987	ROCK CREEK FISHERMANS MERC	12/27/94		0.12
2104	HAWTHORNE SCHOOL	02/05/91		0.60
2119	CANYON PINES HOA	12/29/93		0.29
2120	HIDDEN HEIGHTS SUBDIVISION	06/16/92		0.34
2121	NORTH DAVIS DUPLEXES (421)	12/31/94		0.56
2150	THE OTHER PLACE - TURAH	03/31/92		0.40
2393	GOODAN KEIL HOA	04/21/92		1.80
2396	TACO JOHNS – BROOKS MISSOULA	06/18/92		1.34
2464	STIMSON LUMBER CO - MILLTOWN	02/21/89		0.09
2465	STIMSON LUMBER CO PLYWOOD MILL	02/21/89		0.13
2466	STIMSON LUMBER CO MILLTOWN OFF	02/02/87		0.20
2490	MISSOULA COUNTRY CLUB	05/04/93		2.19
2491	SWAN VALLEY ELEMENTARY SCHOOL	02/05/91		0.10
2492	VILLAGE INN PIZZA – MISSOULA	05/10/89		1.50
2513	SUNWOOD ACRES WATER ASSN	05/19/92		0.90
2517	EL MAR TRAILER VILLAGE & KOA	01/28/92		0.15
2536	FRENCHTOWN ELEMENTARY SCHOOL	03/05/87		1.10

PUBLIC WATER SUPPLY NITRATE DATA

PWS ID	PWS NAME	SAMP DATE	BDL	NO3 N
2537	BIRCHWOOD DUPLEXES	11/01/93		0.86
2538	SUNSET PINES	05/19/92		0.06
2540	LLOYD TWITE WYOMING DUPLEXES	02/02/93		0.57
2541	LLOYD TWITE 7TH ST DUPLEXES	04/04/90		0.93
2543	ALLOMONT APARTMENTS – LOLO	01/17/89		0.69
2580	MISSOULA WATER WORKS	06/22/92		1.15
2633	TRAVELERS INN MOTEL	11/14/94		0.12
2635	OLD HELLGATE VILLAGE – MSLA	02/10/92		1.29
2661	MUSTANG SALLY'S	05/18/92		0.60
2783	BUCK SNORT RESTAURANT – EVARO	12/07/94		3.66
2800	SHELBY SUBDIVISION	04/26/90		0.18
2968	MISSOULA BUS DEPOT	11/28/88		0.40
3012	MISSOULA VILLAGE WEST TR CT	02/07/94		0.41
3013	THE LODGES AT SEELEY LAKE	03/15/95		0.02
3026	SKIPPERS FISH & CHIPS	01/24/91		0.90
3037	FRENCHTOWN CLUB – FRENCHTOWN	01/26/95		0.91
3088	MILLTOWN WATER USERS ASSOC	01/28/92		0.13
3098	MCCORMICK MUNICIPAL POOL	04/07/93		0.63
3115	JIM & MARYS RV PARK	11/15/94		1.91
3146	BITTERROOT MEADOWS HOA – LOLO	09/06/94		0.39
3159	FORT MISSOULA – U.S. ARMY	02/05/91		1.78
3215	MONTANA TRAILER COURT	02/12/91		0.53
3220	DAYS IN MOTEL OF MISSOULA	11/14/94		1.94
3237	VFW TRAILER COURT	05/26/92		1.54
3261	GRINELL ESTATES HOA	04/05/90		0.55
3281	MAPLEWOOD MANOR REST HOME	02/12/91		0.30
3283	C & D HOA – MISSOULA	09/12/94		0.64
3305	GRANT CREEK WATER WORKS	09/06/93		0.23
3392	FRENCHTOWN SHOPPING CENTER	11/28/88		0.70
3442	LINDA VISTA WATER COMPANY	05/03/94		6.94
3505	MISSOULA CO HIGH SCHOOL VO-AG	06/01/92		0.90
3506	U OF M – COLLEGE OF TECHNOLOGY	06/01/92		0.90
3520	M&R TRAILER COURT	06/10/92		0.68
3527	JUNIPER TRAILER COURT – MSLA	12/07/94		0.57
3530	WAREHOUSE VENTURES	05/15/91		2.24
3538	CATLIN STREET TRAILER COURT	06/16/92		0.90
3543	TIDYMANS	05/09/94		0.50
3559	EATS MISSOULA MT WATER – MWC	07/26/92		0.50
3561	NORCO PRODUCTS WELL #1 & #2	11/07/91		1.30
3565	EASTVIEW HOA – MSLA	12/10/91		0.36
3589	HOLIDAY STATION STORE #278	01/30/92		0.50
3615	POTOMAC SCHOOL UPPER WELL #2	05/10/94		0.82
3639	LDS CHURCH MISSOULA 2,3	01/09/95		0.77
3643	LDS CHURCH LOLO	01/09/95		0.76
3644	LDS CHURCH FRENCHTOWN	12/14/94		0.42
3692	KATOONAH LODGES	05/18/94		1.10
3723	FRENCHIES FRENCHTOWN	12/29/94		0.19
3756	WRIGHT LEASING	11/09/94		1.52
3759	MISSOULA COUNTRY CLUB SHOP	05/04/94		1.90
3777	TOWN PUMP #3 – MISSOULA	05/08/95		0.65
42413	BEAVERTAIL HILL STATE PARK	05/16/94		0.26
42414	CHIEF LOOKING GLASS FAS	05/17/94		0.07
42415	FRENCHTOWN POND STATE PARK	05/16/94		0.87

PUBLIC WATER SUPPLY NITRATE DATA

PWS ID	PWS NAME	SAMP DATE	BDL	NO3 N
42416	JOHNSRUD FAS	05/17/94		0.03
42524	SALMON LAKE STATE PARK DAY USE	05/17/94		0.13
42525	SALMON LAKE STATE PARK CG	05/17/94		0.13
42526	PLACID LAKE STATE PARK	05/17/94		0.36
42957	COUNCIL GROVE STATE PARK	05/16/94	N	0.01
43462	RUSSEL GATES MEMORIAL FAS	05/17/94		0.01
43463	RIVER BEND FAS	05/18/94		0.02
62374	RIVERPOINT CAMPGROUND	06/16/93	<	0.01
62375	SEELEY LAKE CAMPGROUND	06/16/93	<	0.01
62377	SLOWAY CAMPGROUND	06/21/93		0.36
62380	ST REGIS WORK CENTER	06/21/93		0.15
62381	QUARTZ FLAT CAMPGROUND	06/21/94		0.16
62578	NINEMILE RANGER STATION	06/21/93		0.08
62786	LAKE ALVA CAMPGROUND	06/16/93	<	0.01

APPENDIX C

COMPARISON OF NITRATE DATA WITH DATA FROM JUDAY AND KELLER, (1978) AND WOESSNER, (1988)

Comparison with wells tested by Juday and Keller (1978)

WELL ID #	JUDAY & KELLER (1978)	STUDY AVERAGE	DIFFERENCE
9	0.85	0.93	+0.08
20	0.37	1.22	+0.85
22	1.45	0.39	-1.06
37	1.55	3.23	+1.68
62	0.67	0.51	-0.16
74	0.75	0.88	+0.13
95	0.03	0.19	+0.16
98	0.64	0.70	+0.06
120	1.27	0.99	-0.28
130	0.32	0.26	-0.06
131	0.98	0.82	-0.16
132	0.86	0.77	-0.09
133	0.84	0.44	-0.40
134	2.50	3.39	+0.89
138	0.68	0.86	+0.18
139	0.70	0.63	-0.07
140	1.38	0.85	-0.53
141	1.12	0.74	-0.38
145	2.07	1.13	-0.94
147	0.76	1.04	+0.28
148	0.70	0.64	-0.06
149	0.13	0.21	+0.08
151	0.32	0.96	+0.64
153	0.58	0.70	+0.12
154	0.73	1.40	+0.67
155	2.07	0.56	-1.51
157	0.56	1.25	+0.69
159	1.05	1.32	+0.27
164	0.95	0.23	-0.72
169	0.04	1.39	+1.35

Comparison with wells tested by Woessner, (1988)

WELL ID #	*WOESSNER (1988)*	*STUDY AVERAGE*	*DIFFERENCE*
44	*1.21*	*1.09*	*-0.12*
55	*0.71*	*0.72*	*+0.01*
61	*0.99*	*1.11*	*+0.12*
83	*1.21*	*1.35*	*+0.14*
130	*0.33*	*0.26*	*-0.07*
151	*0.84*	*0.96*	*+0.12*
163	*0.83*	*0.60*	*-0.23*
196	*0.92*	*0.87*	*-0.05*
197	*0.84*	*0.55*	*-0.29*
198	*0.66*	*1.95*	*+1.29*

APPENDIX D

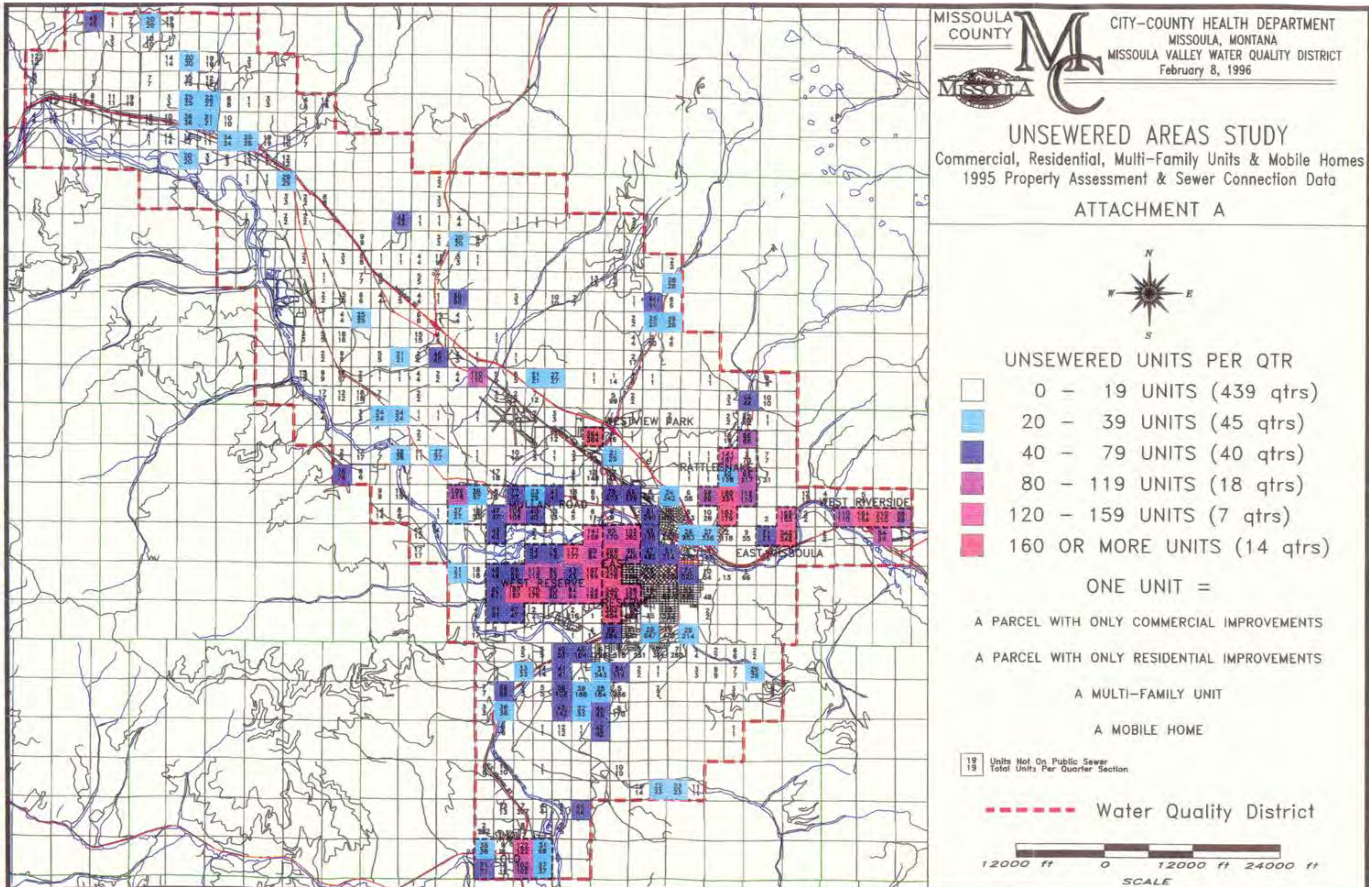
RESULTS FOR NITRATE SPLIT SAMPLES, QA/QC

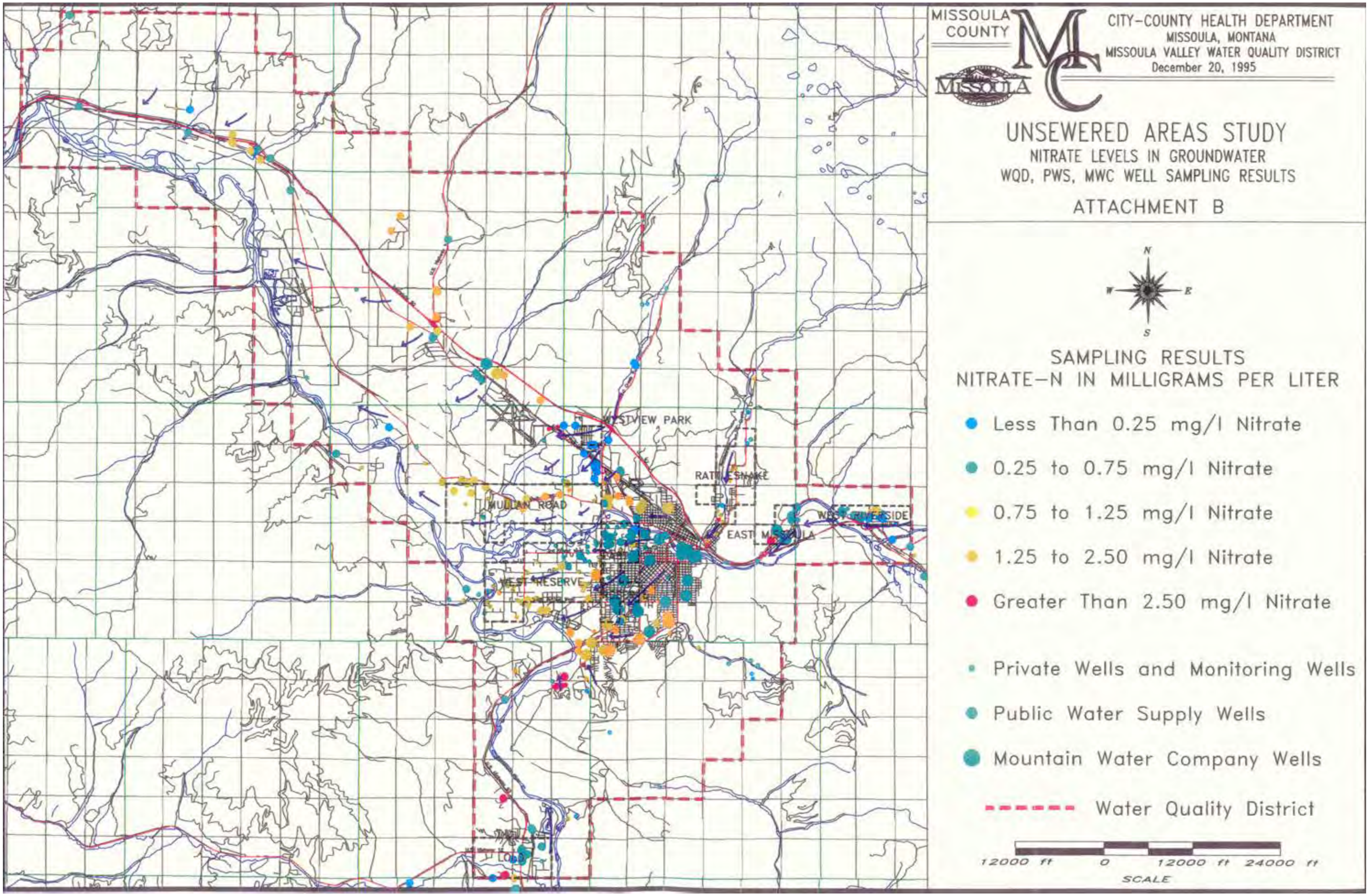
QA/QC
RESULTS FOR NITRATE SPLIT SAMPLES

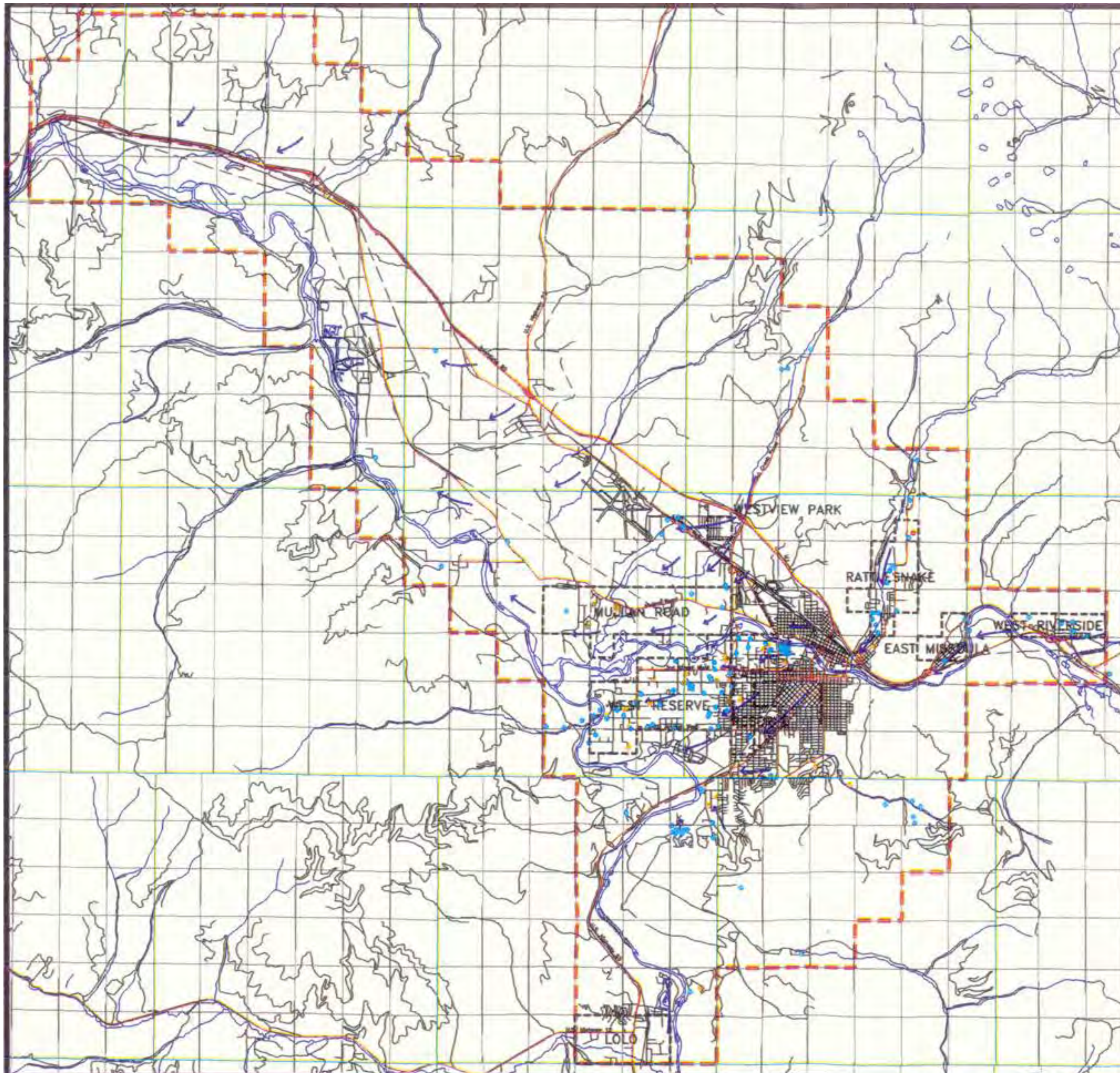
ID	DATE	DHES (mg/l)	UM (mg/l)	DIFFERENCE	RPD(%)
41	05/31/94	0.26	0.30	0.04	14.3
164	06/01/94	0.21	0.23	0.02	9.09
102	06/01/94	0.07	0.09	0.02	25.00
95	06/01/94	0.13	0.17	0.04	26.67
26	06/01/94	0.82	0.79	0.03	3.73
31	06/06/94	0.62	0.66	0.04	6.25
104	06/06/94	0.46	0.49	0.03	6.32
163	06/06/94	0.60	0.62	0.02	3.28
48	06/06/94	0.23	0.25	0.02	8.33
130	06/06/94	0.24	0.26	0.02	8.00
169	06/06/94	1.17	1.18	0.01	0.85
100	06/07/94	0.92	1.00	0.08	8.33
58	06/07/94	0.54	0.56	0.02	3.64
63	06/07/94	0.79	0.85	0.06	7.32
115	06/07/94	1.05	1.00	0.05	4.88
11	06/08/94	0.54	0.54	0.00	0.00
38	06/08/94	0.61	0.64	0.03	4.80
157	06/08/94	0.52	0.53	0.01	1.90
146	06/08/94	0.73	0.79	0.06	7.89
161	06/08/94	0.74	0.78	0.04	5.26
138	6/8/94	0.79	0.87	0.08	9.64
42	6/13/94	0.46	0.47	0.01	2.15
32	2/1/95	0.34	0.37	0.03	8.45
76	2/1/95	1.43	1.48	0.05	3.44
202	2/6/95	1.35	1.40	0.05	3.64
8	2/8/95	0.22	0.25	0.03	12.77
106	5/9/95	0.75	0.77	0.02	2.63
173	5/17/95	9.83	9.5	0.78	8.07
122	5/17/95	0.67	0.69	0.02	2.94
40	5/30/95	1.04	1.12	0.08	7.41
37	5/31/95	3.11	3.24	0.13	4.09

DIFFERENCE=Absolute value of (UM value - **DHES** value)
RPD: Relative Percent Difference; (difference/mean)*100

ATTACHMENTS


MISSOULA COUNTY
CITY-COUNTY HEALTH DEPARTMENT
MISSOULA, MONTANA
MISSOULA VALLEY WATER QUALITY DISTRICT
February 8, 1996
UNSEWERED AREAS STUDY
Commercial, Residential, Multi-Family Units & Mobile Homes
1995 Property Assessment & Sewer Connection Data
ATTACHMENT A
N
S
E
W
UNSEWERED UNITS PER QTR
0 – 19 UNITS (439 qtrs)
20 – 39 UNITS (45 qtrs)
40 – 79 UNITS (40 qtrs)
80 – 119 UNITS (18 qtrs)
120 – 159 UNITS (7 qtrs)
160 OR MORE UNITS (14 qtrs)
ONE UNIT =
A PARCEL WITH ONLY COMMERCIAL IMPROVEMENTS
A PARCEL WITH ONLY RESIDENTIAL IMPROVEMENTS
A MULTI-FAMILY UNIT
A MOBILE HOME
Units Not On Public Sewer
Total Units Per Quarter Section
Water Quality District
12000 ft 0 12000 ft 24000 ft
SCALE
WESTVIEW PARK
RATTLESNAKE
WEST RIVERSIDE
EAST MISSOULA
MULLAN ROAD
WEST RESERVE
LOLO


MISSOULA COUNTY
CITY-COUNTY HEALTH DEPARTMENT
MISSOULA, MONTANA
MISSOULA VALLEY WATER QUALITY DISTRICT
December 20, 1995
UNSEWERED AREAS STUDY
NITRATE LEVELS IN GROUNDWATER
WQD, PWS, MWC WELL SAMPLING RESULTS
ATTACHMENT B
N
W
E
S
SAMPLING RESULTS
NITRATE-N IN MILLIGRAMS PER LITER
Less Than 0.25 mg/l Nitrate
0.25 to 0.75 mg/l Nitrate
0.75 to 1.25 mg/l Nitrate
1.25 to 2.50 mg/l Nitrate
Greater Than 2.50 mg/l Nitrate
Private Wells and Monitoring Wells
Public Water Supply Wells
Mountain Water Company Wells
Water Quality District
12000 ft
0
12000 ft
24000 ft
SCALE
MULLAN ROAD
WEST RESERVE
EAST



MISSOULA COUNTY

CITY-COUNTY HEALTH DEPARTMENT
MISSOULA, MONTANA
MISSOULA VALLEY WATER QUALITY DISTRICT
December 20, 1995

UNSEWERED AREAS STUDY

INDIVIDUAL WELL SAMPLING RESULTS
INDIVIDUAL WELLS EXCLUDING MONITORING WELLS

ATTACHMENT C

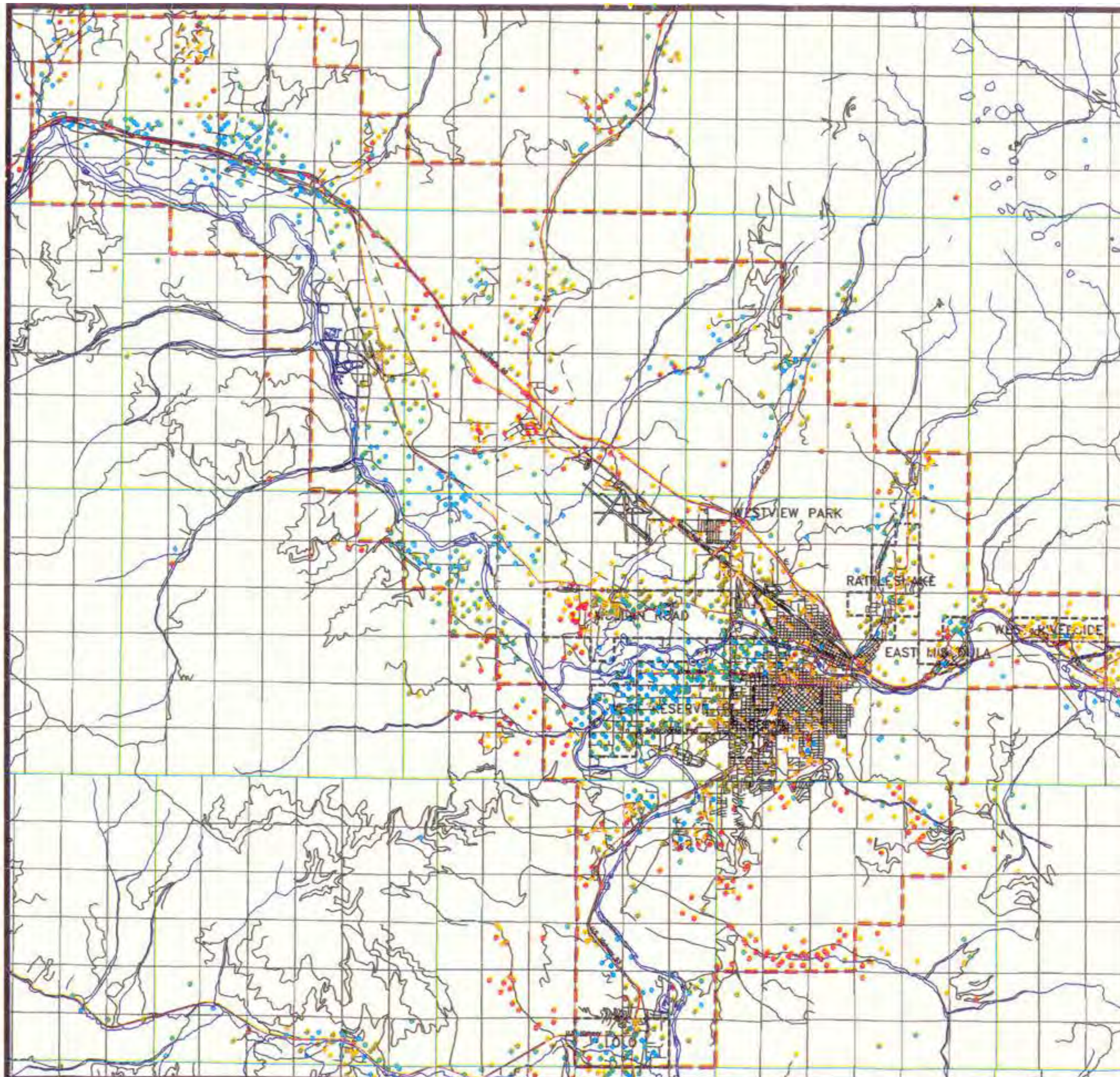
INDIVIDUAL WELL SAMPLING RESULTS
TOTAL COLIFORM MEMBRANE FILTER TEST

- No Bacteria Detected (122)
- Non-Coliform Bacteria Detected (6)
- Total Coliform Bacteria Detected (24)
- Fecal Coliform Bacteria Detected (1)

153 INDIVIDUAL WELLS SAMPLED UP TO 4 TIMES

Water Quality District

12000 ft 0 12000 ft 24000 ft
SCALE



MISSOULA COUNTY

CITY-COUNTY HEALTH DEPARTMENT
MISSOULA, MONTANA
MISSOULA VALLEY WATER QUALITY DISTRICT
December 20, 1995

REPORTED WELL LOCATIONS

Montana Bureau of Mines and Geology Water Well Data
Static Water Level Depths

ATTACHMENT D

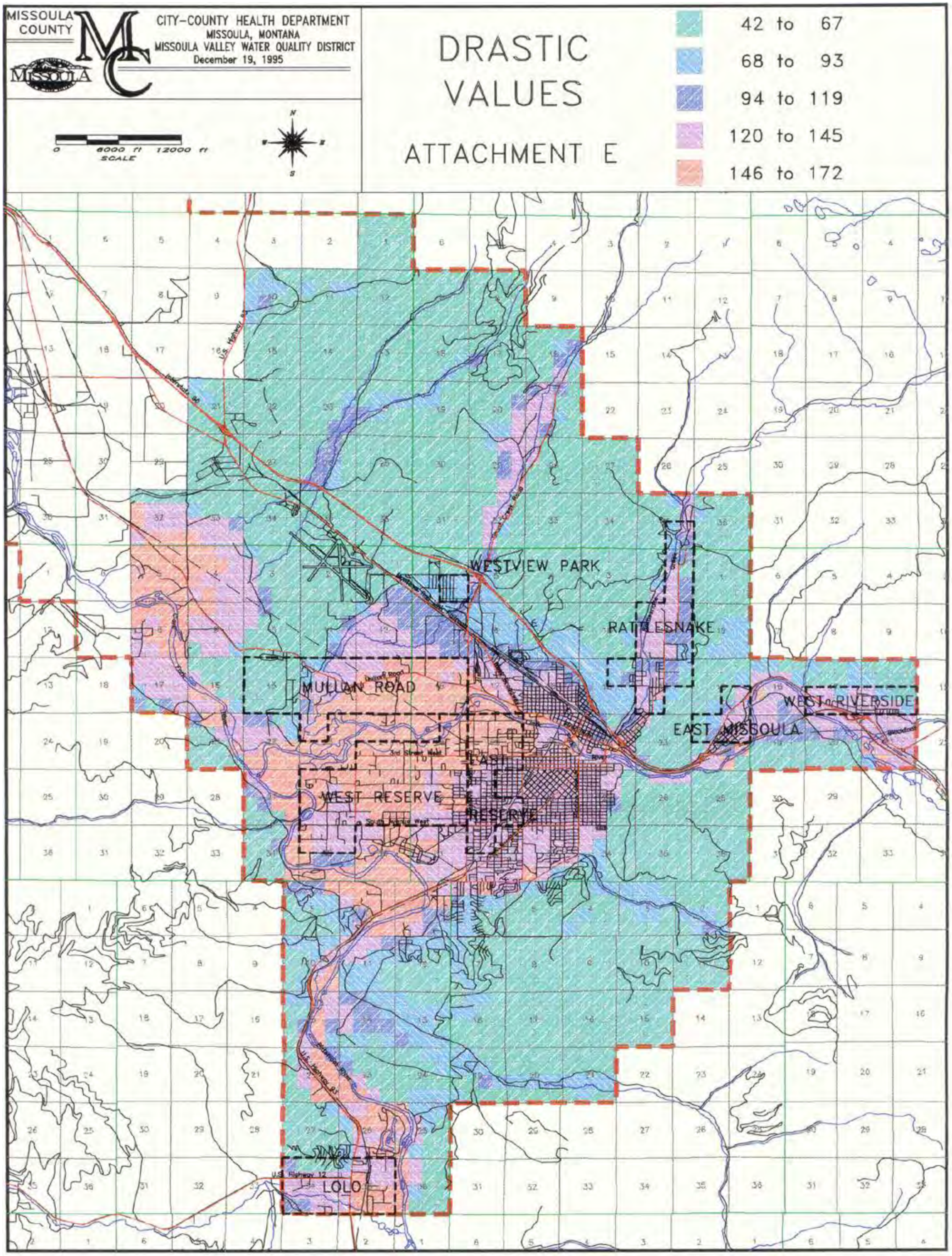
N
W E
S

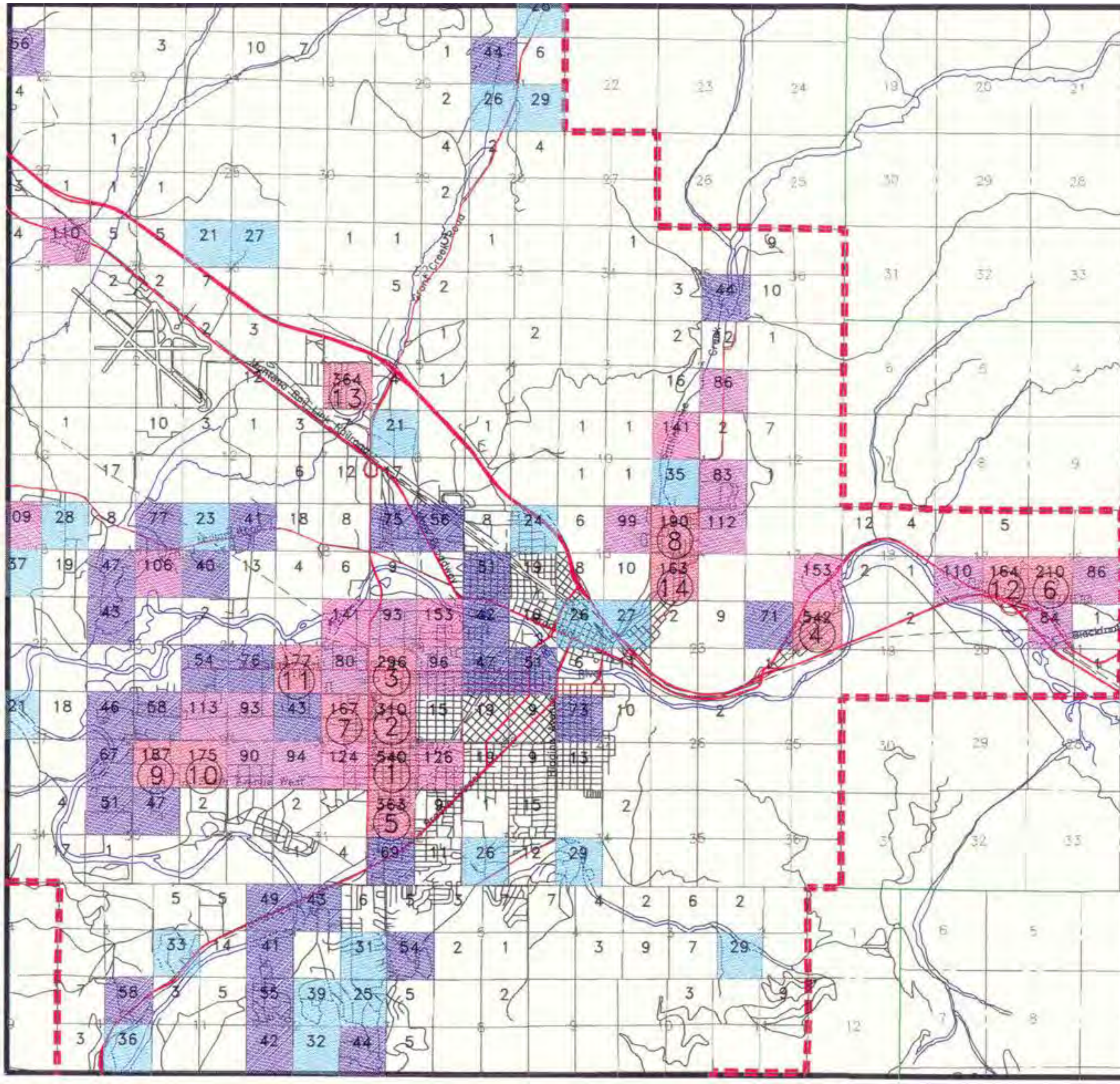
WELL LOCATIONS
STATIC WATER LEVELS

- Less Than 10.0 Feet
- 10.0 To 19.9 Feet
- 20.0 To 39.9 Feet
- 40.0 To 79.9 Feet
- 80.0 Feet and Deeper

Water Quality District

12000 ft 0 12000 ft 24000 ft
SCALE


MISSOULA COUNTY
CITY-COUNTY HEALTH DEPARTMENT
MISSOULA, MONTANA
MISSOULA VALLEY WATER QUALITY DISTRICT
December 19, 1995
DRASTIC VALUES
ATTACHMENT E
42 to 67
68 to 93
94 to 119
120 to 145
146 to 172
0 6000 ft 12000 ft
SCALE
N
S
WESTVIEW PARK
RATTLESNAKE
MULLAN ROAD
WEST RIVERSIDE
EAST MISSOULA
EAST RESERVE
WEST RESERVE
LOLO
U.S. Highway 12



MISSOULA COUNTY

CITY-COUNTY HEALTH DEPARTMENT
MISSOULA, MONTANA
MISSOULA VALLEY WATER QUALITY DISTRICT
February 8, 1996

UNSEWERED AREAS STUDY

Unsewered Density

Highest Density Quarter Section Priority Ranking

ATTACHMENT F

UNSEWERED UNITS PER QTR

0 – 19 UNITS (439 qtrs)
20 – 39 UNITS (45 qtrs)
40 – 79 UNITS (40 qtrs)
80 – 119 UNITS (18 qtrs)
120 – 159 UNITS (7 qtrs)
160 OR MORE UNITS (14 qtrs)

ONE UNIT =

A PARCEL WITH ONLY COMMERCIAL IMPROVEMENTS

A PARCEL WITH ONLY RESIDENTIAL IMPROVEMENTS

A MULTI-FAMILY UNIT

A MOBILE HOME

19 Units Not On Public Sewer

Water Quality District

6000 ft 0 6000 ft 12000 ft

SCALE