

CITY OF BOZEMAN

PWSID MT0000161

SOURCE WATER DELINEATION AND ASSESSMENT REPORT

Prepared for:

City of Bozeman

Bozeman, Montana

PWSID #00161

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February 22, 2001

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1 INTRODUCTION

Source Water Delineation and Assessment is an evaluation performed on public drinking water supplies. The focus of the evaluation is on the supply sources with the intention of identifying potential water contaminants. The city of Bozeman uses three water supply sources: 1) Hyalite Creek (a.k.a. Middle Creek) is a surface water source; 2) Sourdough Creek (a.k.a. Bozeman Creek) is a surface water source; and 3) Lyman Spring, which is a classified groundwater source. [Figure 1-1](#) shows the location of these water sources and the general area of Bozeman, Montana.

Source Water Delineation and Assessment is the first phase of protecting the water quality of public drinking water sources. The second phase prepares a Source Water Protection Plan. This Plan uses the Source Water Delineation and Assessment Report as a technical basis. The Plan describes source water protection management activities that

will be implemented in order to reduce contamination risk. Protection of the source water quality does not begin until these activities are implemented.

The city of Bozeman completed this Source Water Delineation and Assessment Report during summer and fall of 2000. The Source Water Protection Plan will be prepared and implemented during 2001. Implementation efforts will occur indefinitely thereafter.

Regulatory Background

Protection of water supply sources has a long history, but has become more formal since the 1986 Safe Drinking Water Act Amendments were passed. In 1986, the U.S. Congress required EPA to develop a Wellhead Protection Program. This program focused on groundwater supplies used in public water systems. By 1992, EPA had developed their program, which included a requirement for each state to develop a Wellhead Protection Program. The states, including Montana, developed these programs and passed along requirements for Wellhead Protection planning to the public water systems.

In 1996, when new amendments to the Safe Drinking Water Act were passed, Source Water Protection replaced Wellhead Protection. Source Water Protection was an expansion of Wellhead Protection to include surface water sources. The fundamental approach to wellhead protection was adapted to surface water sources. However, EPA developed their Source Water Protection Program in a slightly different manner than the Wellhead Protection Program. EPA made it a requirement that the state agency administering public water systems would be responsible to complete Source Water Delineation and Assessment Reports (SWDARs). This requirement is a burden on the state rather than the individual public water systems.

The state of Montana has developed an EPA-approved Source Water Protection Program and is in the process of program implementation. This program details how the state will complete SWDARs for each water system and describes the content requirements for SWDARs. This SWDAR for the city of Bozeman has been prepared to meet the requirements of the state's program.

As part of the state's Source Water Protection Program, a grant opportunity was made available to public water systems. Grants could be obtained to allow the public water system to complete a certified SWDAR without direct technical assistance from the state. By this approach, the state provides only review and certification of the SWDAR. Many public water systems in Montana, including the city of Bozeman, have chosen this option.

SWDAR Summary

A Source Water Delineation and Assessment Report must meet several content requirements in order to be certified by the state. A checklist completed for this SWDAR is included in Appendix A. A summary of the fundamental elements of an SWDAR are provided below.

Delineation For each source of water, the land area contributing recharge to the source must be mapped. There are several sub-areas that are mapped to complete the delineation. The mapped areas are called Source Water Protection Areas.

Inventory Within Source Water Protection Areas, potential contaminant sources are identified. These sources include any "condition", natural or man-made, that is perceived to have a chance of contaminating the water supply. Typically, these sources consist of properties where chemicals are used and stored, sewer lines, petroleum pipelines, transportation routes, mining and logging operations, animal feeding areas, and recreational areas.

Susceptibility The results of the inventory may identify perceived or known significant sources of contamination. Sources that are considered to have a potentially serious impact on water quality if a release occurs are included in this group. For these sources, a ranking procedure is applied that indicates the susceptibility of the water supply to the contaminant source. The ranking is qualitative, ranging from "low" to "very-high". During preparation of the Source Water Protection Plan, the results of the susceptibility analysis are used to prioritize management activities.

Acknowledgements

The city of Bozeman gratefully acknowledges state funding to prepare this SWDAR. Montana Department of Environmental Quality staff working in the Source Water Protection section also provided valuable comments on the report. City of Bozeman staff from the Engineering and Water Departments provided data and other information for report preparation and also provided review comments on the draft report. The SWDAR was prepared by Western Groundwater Services. DTM Consulting, Inc. provided GIS assistance to delineate the watersheds and to compile digital air-photos of the project area.

1.1 Community

The town of Bozeman originated in 1864 as a business and agricultural community related to gold mining in the mountains to the west. Bozeman is now a growing small city, with a 1998 population of 29,936. The present annual growth rate of 7.2% is very high in comparison to other cities in the US, and also to other cities in Montana. Agriculture, tourism, and government are the principal industries in the Gallatin Valley and in Bozeman. A handful of high technology businesses have shown steady growth in the past several years and are considered large employers. Land development and associated construction has also been a strong industry in the 1990s.

Agricultural sales total approximately \$60 to \$70 million annually, split about evenly between cattle and crops. The gross cash in-flow due to tourism in the Gallatin Valley may exceed \$400 million annually. Montana State University (MSU) is the largest single facility in the area. MSU employs 3,200 professionals and support staff, and also about

2,500 students. Approximately 12,000 students attend the University annually, which is provided water and sewer service by the city of Bozeman.

Water service is provided inside the city of Bozeman limits via a pressurized distribution system with modern water treatment facilities ([Figure 1-1](#)). Sewage collection services are also provided and wastewater is treated to a high-quality effluent at a city-owned plant along the East Gallatin River. The municipal landfill, which accepts solid wastes from Bozeman and non-Bozeman residents, is located on the north side of town.

Interstate 90 separates the north and south sides of the Bozeman water system. Bozeman "proper" is located on the south side of I-90, although growth in the 1980s and 1990s has resulted in significant north-side residential development. Rail through the area parallels the interstate and is operated by Montana Rail Link for commercial freight only. There are no passenger trains into Bozeman at present. Gallatin Field is the local airport and is located about 8-miles west of Bozeman in Belgrade, Montana.

1.2 Geographic Setting

Bozeman is located in Gallatin County in the eastern portion of the Gallatin Valley, which is a broad intermontane basin (Kendy and Tresch 1996). The elevation at Bozeman is approximately 4,800 ft above mean sea level. Gallatin Valley ranges in elevation from 4,100 ft where the Gallatin River leaves the valley on the west side to about 6,000 ft along the southeast boundary. The Gallatin and Bridger Mountain ranges are the most prominent near Bozeman, with summits to 10,000 ft (see [Figure 1-1](#)). The city's Hyalite and Sourdough water sources extend into the Gallatin Range, whereas Lyman Spring originates in the Bridger Mountains.

Historical climate data summarized in terms of the monthly averages are shown on Figures [1-2](#), [1-3](#) and [1-4](#). These data, which are recorded at a weather station on the MSU campus, are summarized below.

- ▶ On a national basis, air temperature in Bozeman would be considered cold in the winter and cool in the summer, however, most Bozeman residents would consider many summer days to be "hot". The temperature pattern follows a generally uniform oscillation, with high temperatures occurring during late July and early August and low temperatures occurring during December and January.
- ▶ Long-term average precipitation shows two peaks, occurring during May and June and then again in September. The wettest months are May and June, and correspond to significant recharge in the area. The September peak is most likely to only replenish some of the soil moisture deficit that exists at the end of summer. With a total precipitation of about 18 inches annually, the Bozeman area has a moderately dry climate.
- ▶ Snow is common in the winter months and not terribly infrequent during June and early July, primarily in the mountains, but also in Bozeman. By mid-September of

each year the summits of local mountains are white capped, and during above average years, ski season begins by Thanksgiving. March brings the largest snowfall, and during dry years can make up significant deficits in a thin snow pack.

1.3 Public Water System

The city of Bozeman owns and operates Water System No. 161 in the state of Montana. The Sourdough/Hyalite source is assigned identification number 002. These two sources are grouped because both feed into the water treatment plant before distribution to the city. The Lyman Spring source is assigned identification number 004.

A recently completed Water Facilities Plan was used to obtain information presented in this section (MSE-HKM 1997). In 1996, the service population included 24,860 people, obtaining water through 5,744 accounts, or connections. The service area for the 20-year planning period ending 2014 is shown on [Figure 1-1](#). Maps of the water service area and sewer collection system presented in MSE-HKM (1997) and MSE-HKM (1998), and can be viewed at city hall. A total of six water department staff are certified water system operators. Table 1-1 lists the city operators and their operator numbers.

TABLE 1-1

WATER SYSTEM OPERATORS

| Name/Title | Operator Number | Responsibility |
|--------------------------|-----------------|----------------|
| Dean Elliot ¹ | 2107 | Superintendent |
| Rick Moroney | 2742 | Chief Operator |
| Jerry DeVantier | 2856 | Operator |
| Eric Campbell | 3128 | Operator |
| Mark VanAntwerp | 2408 | Operator |
| Gerald Peterson | 2634 | Operator |

¹ Primary contact for Source Water Protection Planning at the city of Bozeman Water Treatment Plant (586-7158).

Three water sources serve the city: 1) Sourdough Creek; 2) Hyalite Creek; and 3) Lyman Spring ([Figure 1-1](#)). About 99% of the water supply is obtained from the Sourdough and Hyalite sources. Lyman Spring provides the remaining 1%. The Sourdough and Hyalite sources are treated via a conventional water treatment plant, including flocculation, sedimentation, and filtration. The water is disinfected with chlorine and fluoride is added for dental hygiene purposes. Lyman Spring, a groundwater source, is treated only by chlorine disinfection. It is not presently necessary to treat this source further.

The water system separates into two pressure zones called the South Zone and the North Zone. I-90 marks approximately the line separating the South and North zones. The South Zone water supply is entirely from Sourdough and Hyalite Creeks. The North Zone water supply is from Lyman Spring. In the future, facilities will be added to transmit Lyman Spring water to the South Zone.

Tables 1-2 and 1-3 present data on water use by the city of Bozeman. The city uses about 1.5 to 1.8 billion gallons of water annually (these figures include leakage from the system). The average day demand at present is 4 to 5 million gallons, with a maximum day demand of about 11 million gallons. Peak hour demand has been estimated at a rate equal to 13 million gallons per day (9,028 gallons per minute). In 1996, the usage rate per citizen was 175 gallons per day, slightly high for a mature city (normally 165 gallons per capita day), but considerably lower than smaller Montana communities. Over the next 40 to 50 years, Bozeman is predicted to double in both population and water use.

TABLE 1-2

TOTAL ANNUAL WATER PRODUCTION

| Year | Sourdough and Hyalite Creeks South Zone (gallons) | Lyman Spring North Zone (gallons) |
|------|---|-----------------------------------|
| 1991 | 1,775,360,000 | 18,615,000 |
| 1992 | 1,549,060,000 | 20,440,000 |
| 1993 | 1,449,780,000 | 18,980,000 |
| 1994 | 1,662,210,000 | 26,280,000 |
| 1995 | 1,537,745,000 | 0 (out of service) |
| 1996 | 1,587,020,000 | 0 (out of service) |

TABLE 1-3

MEASURED AND PREDICTED WATER USE RATES

| Parameter | Year 1996 | Year 2014 | Year 2044 |
|---------------------------------|-----------|-----------|-----------|
| Population | 24,860 | 32,510 | 50,240 |
| Average Day Demand ¹ | 4.35 | 6.50 | 10.05 |
| Maximum Day Demand | 10.87 | 16.26 | 25.12 |
| Peak Hour Demand | 13.05 | 19.50 | 30.15 |

¹ Water use rates are in units of million gallons per day.

1.4 Water Quality

Source Water Quality

General water quality data for Sourdough Creek and Lyman Creek presented in Table 1-4 were obtained from earlier work completed by the U.S. Geological Survey (Hackett et al. 1960). The water quality likely has not changed significantly in the past 50 years, and assuming that the analysis methods were adequate, these data are reasonable indicators of general water quality today. The samples were collected during September, and are anticipated to represent base flow water quality in the streams. The water at this time of year is dominantly groundwater that has discharged into the stream channel. With respect to Lyman Creek, it is nearly certain that 100% of the stream flow originated from groundwater.

In terms of general water quality parameters, the data indicate a moderately hard water. Dissolved ion concentrations are low to moderate. In terms of water classifications, the waters are both calcium-magnesium-bicarbonate types. Lyman Creek has more dissolved ions, resulting in greater hardness and specific conductance than Sourdough Creek. Data for Hyalite Creek would be similar to those for Sourdough Creek.

During spring runoff, ion concentrations should be substantially diluted. The hardness is anticipated to decrease to lower levels during this time and would be classified as a soft or moderately hard water. The dilution effect would be greater for Sourdough and Hyalite Creeks. The Lyman Spring water should decrease in dissolved ion content during spring, but the changes may be minor in comparison to the Sourdough and Hyalite sources.

TABLE 1-4

GENERAL WATER QUALITY

| Parameter | Sourdough Creek | Lyman Creek |
|-------------|-----------------|-------------|
| Sample Date | 9/22/51 | 9/22/51 |
| Calcium | 27.1 | 40.1 |
| Magnesium | 8.0 | 16.0 |
| Sodium | 3.2 | 0.5 |
| Potassium | 1.6 | 0.4 |
| Bicarbonate | 120.8 | 170.2 |
| Carbonate | ND | 6.0 |

| | | |
|--|-------|-------|
| Sulfate | 8.2 | 18.3 |
| Chloride | 0.4 | 1.1 |
| Hardness (mg/L as CaCO ₃) | 100.6 | 166.0 |
| Specific Conductance (uS/cm) | 208 | 306 |
| All units are mg/L unless noted otherwise; ND indicates not detected; hardness was calculated. | | |

Safe Drinking Water Act Compliance

The city of Bozeman meets all water quality regulations according to the Safe Drinking Water Act. Appendix B includes a data table pertaining to samples of finished water from the water treatment plant (combined Hyalite and Sourdough sources) and from Lyman Spring. These sample data were obtained from the Water Facility Plan (MSE-HKM 1997), and were collected in the mid-1990s.

Consumer Confidence Reports

The city of Bozeman has prepared a consumer confidence report on water quality during 1999. Consumer confidence reports will be prepared annually, with 1999 being the first year for this requirement under the Safe Drinking Water Act. Excerpts from the city of Bozeman 1999 Consumer Confidence Report are provided below. A complete copy of the report can be obtained directly from the city.

Listed in Table 1-5 are the contaminants found in Bozeman's drinking water after treatment during the 1999 calendar year. The Environmental Protection Agency (EPA) and the State of Montana Department of Environmental Quality require monitoring of over 80 contaminants. Only those contaminants that were detected in the water supply are shown. Additional data pertaining to frequently

requested information from the Water Treatment Plant are provided in Table 1-6. These data also apply to only the finished, or treated water.

DEFINITIONS

Action Level (AL): The concentration of a contaminant which, if exceeded, triggers treatment, or other requirements, which a water system must follow. Ninety percent of samples must be at, or below, this level. Lead and copper are measured at the 90th percentile.

Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.

Maximum Contaminant Level (MCL): The highest level of a contaminant allowed in drinking water. MCLs are set as close to MCLGs as feasible, using the best available treatment technology.

Nephelometric Turbidity Units (NTU): The level of turbidity in filtered water

ppm: parts per million

ppb: parts per billion

Treatment Technique (TT): Required process intended to reduce the level of a contaminant in drinking water.

TABLE 1-5

1999 DETECTED CONTAMINANTS

| Contaminant | Detected Level | Range | MCL or AL | MCLG | Typical Contaminant Sources |
|-----------------------------|-----------------------|-----------|--|---------|---|
| Nitrate +Nitrite (ppm) | 0.02 | -- | Nitrate - 10 ppm MCL Nitrite - 1 ppm MCL | 10 1 | Runoff from fertilizer use; leaching from septic tanks; sewage; erosion of natural deposits |
| Total Trihalomethanes (ppb) | 21.57 (average) | 15.4-28.0 | 100 MCL | 0 | By-product of drinking water chlorination |
| Lead ¹ (ppb) | 3.0 | -- | 15 AL | 0 | Erosion of natural deposits; corrosion of household plumbing systems |
| Copper ¹ (ppm) | 0.13 | -- | 1.3 AL | 1.3 | Corrosion of household plumbing systems; erosion of natural deposits |
| Fluoride (ppm) | 1.02 (average) | 0.32-1.23 | 4 | 4 | Erosion of natural deposits; water additive which promotes strong teeth |

| | | | | | |
|---|------|------------|---------------------------|-----------------|-------------------------------|
| Turbidity ² (NTU) | 0.16 | 100% < 0.5 | TT=Max < 5.0 TT=95% < 0.5 | Not Established | Natural result of soil runoff |
| <p>¹Lead and copper are sampled at domestic fixtures. The 90th percentile value of all samples is reported. Lead has not been detected in Bozeman source water.</p> <p>²Turbidity has no health effects. However, turbidity can interfere with disinfection and provide a medium for microbial growth. Bozeman's filtered water must be less than, or equal to, 0.5 NTU in at least 95% of monthly measurements, and it can never exceed 5 NTU. The single highest measurement was 0.16 NTU. Bozeman's average daily turbidity was 0.04 NTU.</p> | | | | | |

TABLE 1-6

1999 SUPPLEMENTARY WATER QUALITY DATA

| Parameter | MCL | Range | Average |
|---|---------------------------------|--------------|---------|
| Alkalinity (mg/L as CaCO ₃) | -- | 59.2 - 116.4 | 88.95 |
| Chlorine residual (mg/L) | 4 ¹ | 1.18 - 1.91 | 1.5 |
| Fluoride (added) (mg/L) | 2 ² , 4 ¹ | 0.32 - 1.23 | 1.02 |
| Calcium (mg/L) | -- | 4.13 - 29.76 | 23.97 |

| | | | |
|--|----------------------|----------------|-------|
| Magnesium | -- | 4.00 - 22.08 | 8.37 |
| Hardness, calcium (mg/L as CaCO ₃) | -- | 41.20 - 74.40 | 61.97 |
| Hardness, total (mg/L as CaCO ₃) | -- | 63.60 - 138 | 93.02 |
| PH (standard units) | 6.5-9.3 ¹ | 8.08 - 9.05 | 8.55 |
| Sodium (mg/L) | 20 ³ | 2.48 - 15.10 | 7.94 |
| Sulfate (mg/L) | 500 ² | ND - 7.50 | 0.02 |
| Iron (mg/L) | 0.3 ² | ND - 0.12 | 0.02 |
| Total dissolved solids (mg/L) | 500 ² | 68.20 - 116.90 | 96.17 |
| Turbidity (daily average) (NTU) | 0.5 ¹ | 0.02 - 0.16 | 0.04 |
| Total coliforms (cfu/100 ml) | 1 ¹ | ND | ND |

Notes:

All data shown above apply to treated water from the city of Bozeman Water Treatment Plant.¹ Primary drinking water standard; ² Unenforceable secondary standard; ³ Guidance. ND indicates not detected in any samples.

Water Treatment Plant Turbidity Data

Figures [1-5](#) and [1-6](#) present raw water turbidity data obtained from the Water Treatment Plant. Turbidity is an indirect measure of suspended matter in water. This material consists of silt and clay, soluble organic compounds, organic matter, algae, and other microorganisms. The particle sizes range in diameter from about 10 nanometers to 0.1 millimeters (Chapman 1992). Turbidity is an indirect measure of these particles, based on the scattering of a light beam through a water sample. Normal ranges of turbidity in surface water are 1 – 1,000 NTU (Nephelometric Turbidity Units).

Both Sourdough and Hyalite Creeks contribute to the turbidity data shown on Figures [1-5](#) and [1-6](#). Average values for the raw water range from about 0.5 to 22 NTU. Low values, slightly less than 1 NTU are measured during most of the time period from August to February, with some exceptions. The peak turbidity events occur from March to June, and are related to spring runoff. High turbidity events also occur in July and August, most likely due to high runoff from thunderstorms. The data are generally stable, with a repeating cycle from year to year. There does not appear to be a visible trend over the three year record. Daily maximum turbidity, shown on Figure [1-6](#), exhibits the same pattern as the average values, but ranges from about 0.6 up to 400 NTU.

TMDLs and the 303(d) List

In compliance with the federal Clean Water Act, the state of Montana Department of Environmental Quality (DEQ) is in the continuous process of conducting water quality assessments on surface waters, such as Hyalite Creek and Sourdough Creek. These assessments have the purpose of identifying the impaired or threatened condition of the waterbody with respect to designated uses (e.g., drinking, swimming, agriculture, industry).

Every two-years since 1992 the state has submitted a list of impaired and threatened waters to EPA, referred to as the 303(d) list. A draft 303(d) list was prepared in April 2000 and is in the review process (DEQ 2000). The 303(d) list submitted by the state must include a prioritization of the listed waterbodies for the development of plans to improve water quality or prevent future threats to water quality. Best management practices are normally included in the plans as activities to mitigate poor water quality or threatened status. Some of these plans involve development of the total maximum daily load (TMDL) for selected pollutants, and consequently, the plans have been referred to as TMDL plans. A TMDL limits the loading of a pollutant that can occur into the waterbody while meeting water quality standards. Many waterbodies that appear on the 303(d) list will not actually have TMDLs developed, as other management methods will be implemented to improve water quality.

New state legislation passed in 1997 required that waters be 303(d) listed only when sufficient credible data (SCD) were available to properly classify the stream. In past practice, the state had listed waterbodies when there were inadequate or questionable data and the new legislation was intended to prevent these entries. The 1997 legislation resulted in removal of many streams from the earlier 303(d) lists. These streams are scheduled for reassessment and classification according to a schedule presented in DEQ (2000), and based on sufficient credible data.

There are also existing streams in the state that are not yet considered for water quality assessments, and consequently they cannot be 303(d) listed. There is no record of these waterways in the state's assessments; the streams are entirely absent. Many of these absent streams are located in areas where one or more streams have been evaluated. The state is presuming water quality would be similar among the streams of the area. The absent streams are also likely to be unimpaired (i.e., the state has left out certain streams that it does not believe would be impaired, most likely due to an absence of historic water quality problems, a favorable geographic location, and a low level of land development).

Sourdough Creek has not been evaluated for inclusion on the 303(d) list. It is one of the absent streams that simply does not appear in the records. Hyalite Creek, however, has been evaluated in the lower reaches, and it is the next major drainage west from Sourdough. The land uses vary, but it is likely that both streams are in similar condition. Hyalite would be the more "impaired" of the two.

Hyalite Creek was listed as impaired with low priority from the National Forest Boundary to the confluence with the East Gallatin River. The stream was listed in this segment because the state concluded that it could only partially support swimming as a form of recreation. Data were insufficient to assess: 1) growth and propagation of aquatic life, waterfowl, and furbearers; 2) growth and propagation of salmonid fishes; 3) growth and propagation of non-salmonid fishes; 4) drinking water; 5) agricultural water supply; and 6) industrial water supply. Dewatering due to irrigation withdrawals is indicated as the likely cause of the impairment.

The upper part of Hyalite Creek, from the headwaters to the National Forest Boundary, was not assessed due to insufficient credible data. This portion of the stream is therefore a waterbody that will be monitored and reassessed in the future. It is not scheduled for reassessment during 2000 – 2001, but likely will be reassessed before 2006. The city of Bozeman intake on Hyalite Creek is inside the National Forest Boundary, which strongly suggests the state should find this reach of the stream is unimpaired, as evidenced by its use for drinking water. The successful fishery in this part of Hyalite Creek also indicates it should be given an unimpaired status.

1.5 Source Water Sensitivity

Based on the types of sources from which the city of Bozeman obtains water supply, the source may be classified in terms of its sensitivity. Sensitivity refers to the ability of the source to be contaminated, or otherwise impacted, by man's activities. Sources that have

low sensitivity have a natural protective barrier. Sources that have high sensitivity are essentially without a barrier. Releases of contaminants can migrate freely to a high sensitivity source, whereas many years of travel are required for a contaminant to reach a low sensitivity source. Table 1-7 summarizes the sensitivity classes for the city of Bozeman water sources.

The surface water intakes on Sourdough Creek and Hyalite Creek are exposed at the land surface and therefore are vulnerable to contamination. Both of these surface water sources are classified as High Sensitivity. Lyman Spring, which is a groundwater source, is also classified as High Sensitivity. This classification applied to Lyman Spring is attributed more to uncertainty than it is the known vulnerability of the spring. Groundwater flow paths to the spring are difficult to map, and consequently, the level of natural protection by geological materials is unknown. Fractured bedrock, which characterizes the spring aquifer, can also allow contaminants to move greater distances more rapidly than a porous, sand and gravel, aquifer setting.

TABLE 1-7

SOURCE WATER SENSITIVITY

| Source Name | Source Type | Sensitivity Classification |
|-----------------|-----------------------------|----------------------------|
| Sourdough Creek | Surface Water | High |
| Hyalite Creek | Surface Water | High |
| Lyman Spring | Fractured Carbonate Bedrock | High |

1.6 Source Water Intakes

This section provides additional information on the intake areas for the city of Bozeman water sources.

1.6.1 Sourdough Creek

The Sourdough Creek intake is located on city-owned property. Fencing and no-entry signs protect the land area around the intake from inadvertent entry. However, deliberate entry would not be stopped by these barriers. The intake consists of a small concrete dam across the stream channel that creates an upstream pool. A steel perforated intake pipe located in the pool provides the intake. A gate valve can be used to prevent water entry into the pipeline. [Figure 1-7](#) illustrates the intake layout.

At present, water flows from the intake pipe to a settling pond, approximately 100 yds below the intake pool. From the settling pond, water flows via a buried pipeline to the city water treatment plant. During 2001, the city will reconstruct the intake area and at this time, the settling pond will be taken off-line.

There are no eminent sources of contamination present in the intake area. The land surrounding the intake is an undeveloped riparian area. The access road up the drainage, however, passes along the east edge of the intake pool. Vehicle traffic on this road poses a spill risk to the channel in the event of an accident. This road is closed to the general public for motorized vehicle travel. The city of Bozeman and the U.S. Forest Service may use motorized vehicles on this road when working in the area.

1.6.2 Hyalite Creek

The Hyalite Creek intake is located on Gallatin National Forest land in the Hyalite Creek channel. There are no fences or signs that prohibit entry to the intake area. The intake area has become an undeveloped recreational area for fishing and picnicking. There are no facilities developed at the intake, however, parking and a trail provide a convenient access to the stream. During favorable weather, it is common that recreation use of the intake area will occur.

The Hyalite Creek intake is located at a concrete dam across the stream channel. This dam creates a large pool on the upstream side. The city of Bozeman intake consists of a concrete channel in the dam that feeds the pipeline to the water plant. The intake is protected from entry of large debris by a 1-inch steel bar screen. [Figure 1-8](#) illustrates the Hyalite Creek intake area.

No sources of contamination are present at the intake, which is surrounded by undeveloped riparian lands. The Hyalite Creek Road (FS #62) is a paved roadway immediately above the intake to the east. Vehicle accidents on this road pose a spill risk to the channel. This road is heavily traveled in the area of the intake throughout most of the year, but particularly during the summer months.

1.6.3 Lyman Spring

Lyman Spring is developed with two intake locations, that are about 500 ft from one another. The intakes are located on city-owned land on the edge of Gallatin National Forest. Land entry from the Bozeman area is prevented by fencing and no trespassing signs about 2-miles below the spring. Neighboring private landowners can access the area of the spring intakes. Deliberate trespassers also can access this area. Hikers in the Bridger Mountains could walk down a steep drainage to the spring area without passing any fences or signs, although this entry way is unlikely.

The spring intakes consist of horizontally lying perforated PVC pipe. The pipe is set in a gravel filter pack and buried. Turf and wild flora have grown over the pipe areas. There are two intake locations at the spring. A gate valve below the intakes can be closed to

prevent spring water inflow to the water system. [Figure 1-9](#) illustrates the spring intake layout.

There are no sources of contamination present in the spring area, as it consists of remote undeveloped lands. Lyman Spring is likely the most naturally-protected of the city's water intakes, simply due to its location. The spring has been evaluated for surface water influence and was classified as groundwater. This designation indicates that potential contamination by wildlife is also unlikely.

2 DELINEATION

Delineation consists of mapping Source Water Protection Areas – protection regions that surround the water supply intakes. The protection regions provide a focus for management activities. The smaller inner regions receive the highest level of protection. The larger more distant regions are managed less stringently, relying partially on natural purification should a contamination event occur.

The surface water sources, Sourdough Creek and Hyalite Creek, are delineated differently than the Lyman Spring groundwater source (see locations on [Figure 2-1](#)). For each surface water source there are two regions delineated. These regions include:

- ▶ Spill Response Region This region is a ½-mile wide buffer on either side of the surface water body, beginning at the source intake and extending upstream to the head of the watershed. When a large reservoir is present, such as Hyalite Reservoir, the Spill Response Region extends only ½-mile up the tributaries feeding the reservoir.

- ▶ Watershed This region includes the entire topographic watershed above the location of the source intake. [Figure 2-1](#) presents a map of the city of Bozeman watersheds.

There are three regions delineated for each groundwater source. These regions include:

- ▶ Control Zone This region is a circular area with a radius of 100-feet. It is centered on the source intake.

- ▶ Inventory Region For confined aquifer settings, this region is a circular area with a radius of 1,000-feet, centered at the source intake. In unconfined aquifer settings, the inventory region is computed based on groundwater hydraulics. It surrounds the intake and extends up-gradient ("upstream") to the 3-year time-of-travel boundary for groundwater to flow to the source (i.e., all groundwater within the inventory region flows to the source in a time period less than 3-years). In an unconfined bedrock

aquifer, such as Lyman Spring, the Inventory Region is delineated based on hydrogeological mapping. In this approach, the most important land areas contributing recharge to the spring are identified on a map based on hydrogeological analysis. Groundwater travel time is not computed.

► Recharge Area This region includes the entire recharge area to the source. Often this area will coincide with a topographic boundary, but not necessarily. Boundaries exist that limit flow or that supply recharge, which can limit the extent of the recharge area to a groundwater source.

2.1 Delineation Methods and Limitations

As noted above, delineation of Source Water Protection Areas varies for surface water and groundwater sources. Consequently, the method of delineation and the associated limitations of these methods also vary.

2.1.1 Surface Water Methods and Limitations

Spill Response Region

The spill response region is delineated by geographic information system (GIS) software. ArcView GIS was used in all GIS applications for this project (ESRI 1996). Line segments were created along the surface water body (Hyalite and Sourdough Creeks) beginning at the source intake and continuing to the uppermost extent of surface water in the watershed. In the case of Hyalite Creek, line segments were limited to ½-mile upstream along tributaries from Hyalite Reservoir. The same approach was used for the lone tributary stream into Mystic Lake, which occurs at the head of the Sourdough drainage. The ArcView GIS buffer command was applied to the line segments, with a buffer width of 2,640 feet, or ½-mile. The newly created buffer was saved as an ArcView shapefile.

By application of the ArcView GIS buffer command, it becomes possible for the Spill Response Region to extend outside of the watershed. Manual editing of the Spill Response Region boundary was performed to ensure this region was mapped entirely inside of the Watershed Region.

Watershed Region

Watershed regions were delineated using the Spatial Analyst Extension of ArcView GIS. Digital Elevation Models (DEMs) were downloaded from the U.S. Geological Survey. The DEMs consist of 30-meter by 30-meter grid cells with a grid-centered elevation. Hydrologic Analysis Tools in the Spatial Analyst Extension were used to map topographic divides for sub-basins and the watersheds.

Limitations

There are several limitations that apply to the delineation of the Spill Response and Watershed Regions. In general, however, the methods are conservative and it is unlikely that significant errors exist. The limitations may be summarized as follows:

It is assumed that the Spill Response Region, based on ½-mile wide buffers will include all land areas where there may be significant sources of contamination to the water supply. It is possible but unlikely that significant source of contamination could exist outside of this Region.

It is assumed that the Watershed Region encompasses the entire recharge area to the water supply source. While true in the vast majority of surface water drainages, it is possible that inter-basin transfer of groundwater may occur, with discharge to surface water. In these limited cases, the Watershed Region would underestimate the total recharge area to the source.

Delineations are based on mapping data, such as the locations of stream channels and the land surface elevation. There are errors associated with these data, related to the accuracy of the original maps and changes in the land surface that may have occurred since the maps were first created. DEMs have an associated vertical accuracy of ± 7 -meters and a horizontal accuracy of ± 30 -meters. It is possible that stream channel locations may have associated errors of ± 500 -feet, which equates to ¼-inch on a 1:24,000 topographic map.

The implications of these limitations are that boundaries of Source Water Protection Areas should not be considered exact, but more as guidelines. As a safety measure, important land uses occurring in proximity to boundaries should be evaluated as if they occur in the inner-most zone (more stringently managed). As new information is learned about the hydrology of an area, it may be necessary to revise the delineation of Source Water Protection Areas. Such revisions are particularly necessary when evaluating groundwater sources.

2.1.2 Groundwater Methods and Limitations

Lyman Spring is a groundwater source and consequently, it is delineated by groundwater methods. The spring is classified as an unconfined aquifer in bedrock materials. Because bedrock formations are normally dominated by groundwater flow in fractures, the application of standard groundwater models can be difficult. The standard models are developed for porous media groundwater conditions, such as flow in a uniform sand or gravel deposit.

Rather than applying the standard groundwater models to delineate Lyman Spring, the hydrogeologic mapping method was applied. This method was used to map the Inventory Region and the Recharge Area for Lyman Spring. Note that the Control Zone, consisting

of a 100-foot fixed radius area at the spring is mapped without consideration of hydrogeology.

Recharge Area

The Recharge Area to Lyman Spring was mapped by considering spring elevation, total discharge of the spring, and the estimated recharge to groundwater in the southern Bridger Mountains. The Recharge Area was determined as the area in which the recharge rate to groundwater was approximately equal to the discharge rate from Lyman Spring (measured in Lyman Creek). The Recharge Area was generally centered on the Bridger Ridge and was located at higher elevation than the spring (~5,600 ft msl).

Inventory Region

The Inventory Region was mapped based on the surface outcrops of geological formations that are considered to have aquifer properties (in contrast to aquitard properties which have extremely limited groundwater flow rates). Existing geological mapping of these formations was used to delineate the Inventory Region. If an aquitard was located between the surface outcropping of two aquifer formations, it also was included in the Inventory Region. A 500 ft to 1,000 ft buffer zone was also included in the Inventory Region. The Inventory Region was limited to occur only inside of the Recharge Area.

Limitations

Delineation of Lyman Spring was intended to be moderately conservative, providing for large Source Water Protection Areas. In this sense, the method employed does not have significant limitations with respect to Source Water Protection Planning.

There is, however, a large associated uncertainty in geological and hydrogeological evaluations. This uncertainty exists in relation to estimates of groundwater recharge, estimates of the Lyman Spring discharge, mapping of geological contacts and faults, and classification of formations as aquifers and aquitards. The uncertainty can result in differences between actual and mapped Source Water Protection Areas.

The Recharge Area is based on a water balance for Lyman Spring. If the groundwater recharge rate is less than the estimated rate, the mapped Recharge Area will be smaller than the actual Recharge Area. The Recharge Area is also located, by assumption, to be approximately centered on the Bridger Ridge. This assumption could be incorrect, in which case, the actual Recharge Area may in part be located outside of the mapped Recharge Area.

Mapping of the Inventory Region is based on geological mapping and classification of formations as aquifers and aquitards. This mapping method assumes that aquifer formations are more important contributors of groundwater than aquitards, and that geological mapping in the area is generally accurate. It is likely that geological contacts

may be incorrectly located, with offsets of 100 to 500 feet. Formations could also be wrongly designated as aquifers and aquitards. Misclassification becomes more likely in the Bridger Mountains due to the abundance of fractures that exist in the rocks.

2.2 Surface Water Delineation

The Sourdough and Hyalite Creek surface water supplies are primarily recharged by precipitation that falls onto the land surface within the topographic boundaries of the watershed. This precipitation can migrate directly to the creeks as surface runoff. It can also infiltrate the ground and later discharge into the creeks as groundwater discharge. It also becomes stored in the snow pack, and later moves into the creeks as surface runoff. During spring, the majority of water in the creeks is from direct runoff and snowmelt. During late summer, fall and winter, the majority of water in the creeks is from groundwater discharge. In the case of Hyalite Creek, a large proportion of water is stored in Hyalite Reservoir during the spring runoff period, and this water is released through the summer and fall, supplementing the natural groundwater discharge.

Sourdough and Hyalite Creeks are drainages with many similarities. Both emanate from the Gallatin Range south of Bozeman and are separated by only a few miles of mountain ridges. The headwater areas are separated by only a mountain pass. Land cover consists primarily of conifer forests with locally dense shrubs and bushes, thinning at higher elevation. Stream channel margins also are heavily vegetated. The headwater areas are characterized by lower-density alpine vegetation, with mountain summits extending 1,000 to 2,000 vertical feet above tree-line.

Both channels are presently down-cutting through unconsolidated sediments, although bedrock also occurs in the channel bottoms. The channels are generally straight runs without meanders. Erratic bends occur, mostly as a result of resistant geological conditions. A typical mixture of riffles and pools occur repeatedly down the channels. Riffle bottoms are primarily freestone gravel, cobbles, and moderately large boulders, whereas finer grained sediments have accumulated in the pool areas. Due to differences in geological conditions, Sourdough Creek transports a much finer bedload than Hyalite Creek. The Hyalite Creek channel contains a multitude of large boulders, creating a more classic "pocket water" fishery. These boulders appear to be primarily Archean basement rocks, consisting of schist and gneiss.

Large erosional events are limited due to the vegetative cover in both drainages, although it is possible for a limited number of bank sloughs to occur during high water periods. The streams generally run clear year round, with relatively low turbidity. During spring runoff, whitewater conditions are common along nearly the entire channel length of both streams.

One of the major differences between the two watersheds is the presence of Hyalite Reservoir in the Hyalite drainage. This reservoir is fed by several tributaries from the adjacent mountain highlands. It adds considerably to the residence time of these

discharges in the drainage. It also acts as a sedimentation basin, removing the majority of the particulate matter that is eroded from the tributary channels.

The headwater area of Sourdough Creek includes Mystic Lake, a much smaller waterbody in comparison to Hyalite Reservoir. Mystic Lake has the same effects of sedimentation and increased residence time. It is fed by one of the two upper tributaries in the Sourdough Creek watershed. Mystic Lake is a natural lake that was dammed to increase storage by the Army Corps of Engineers. The dam was operated by the Bozeman Creek Water Users Association. It was intentionally breached in 1984 – 1985 due to unsafe conditions related to unstable geology.

2.2.1 Sourdough Creek

In the vicinity of the city of Bozeman intake, the Sourdough Creek channel gradient averages 2.9%, (2.9 feet per 100 feet). Discharge data for the period from 1951 – 1953 for Sourdough Creek were obtained from the U.S. Geological Survey website (<http://waterdata.usgs.gov/nwis-w/MT/>). These data were collected at a temporary gauging station located approximately 2,000 feet upstream from the intake.

[Figure 2-2](#) presents a stream hydrograph, with discharge plotted versus time. Peak flow for the period of record was 233 cubic feet per second (cfs), with the peak occurring during May of each year. Low flow conditions were consistently in the range from 5 to 10 cfs and occur during late winter. The discharge is presented in terms of probabilities on [Figure 2-3](#). A median (50% probability) discharge of 17 cfs was determined from these data. The 90th and 95th percentiles were 72 cfs and 112 cfs, respectively. By assuming a rectangular channel profile and applying Manning's equation, stream flow velocity was estimated as a function of stream discharge (Gupta 1989). The estimated velocities are shown on [Figure 2-4](#) plotted versus the stream discharge. Stream flow velocity associated with the median flow rate of 17 cfs is estimated at 3.21 feet per second (fps), indicating a 4-hour travel distance of 8.75 miles. Mystic Lake is located only 6.4 miles upstream from the intake. Stream flow velocity increases to 4.45 fps for the 90th percentile flow (72 cfs) and to 4.65 fps for the 95th percentile flow (112 cfs).

[Figure 2-5](#) presents the delineated Watershed and Spill Response Regions for the Sourdough Creek intake. The Watershed Region is mapped to the topographic boundaries of the drainage. It extends below the intake as shown on the figure, however, for Source Water Protection Planning only those areas above the intake are of interest. The total area of the Watershed Region is 33 square-miles. The Spill Response Region is mapped as the ½-mile buffer on either side of Sourdough Creek, extending to the headwaters or ½-mile up the tributary into Mystic Lake. The Spill Response Region has a total area of 12 square-miles.

2.2.2 Hyalite Creek

The channel gradient of Hyalite Creek near to the City's intake averages 3.1% (3.1 feet per 100 feet), essentially the same as for Sourdough Creek. There is a substantial record

of stream flow data for Hyalite Creek, and a U.S. Geological Survey stream gage is presently in operation. The gage is located approximately 3,000 feet upstream from the intake. To characterize stream flow for this report, a period of record from 1986 to 1994 was selected. The data were downloaded from the U.S. Geological Survey website, as noted above.

Figures [2-6](#) through [2-8](#) present information to characterize the Hyalite Creek stream flow. The hydrograph shown on [Figure 2-6](#) illustrates the typical pattern of discharge occurring on an annual period. Peak stream flow occurs during May and June, with flows in the range from 400 to 500 cfs. The low flows of late winter are in the range from 15 to 25 cfs. The probability of stream flow rate, based on the observed data, is provided on [Figure 2-7](#). Median flow rate is 36 cfs. The 90th and 95th percentile flow rates are 145 and 200 cfs, respectively. Stream flow velocity was estimated based on the volumetric flow rates, Manning's equation, and the assumption of a rectangular channel. [Figure 2-8](#) provides the estimated velocities, ranging from about 2.5 to 5 fps. Stream flow velocity corresponding to the median flow is estimated at 4.1 fps indicating a 4-hour travel distance of 11.2 miles. Hyalite Reservoir is located only 7.8 miles upstream from the intake. The 90th percentile flow corresponds to an estimated velocity of 4.8 fps. The 95th percentile flow corresponds to a slightly greater estimated velocity of 4.9 fps.

Source Water Protection Areas for the Hyalite Creek intake are presented on [Figure 2-9](#). The Watershed Region includes the entire Hyalite Creek drainage, above and below Hyalite Reservoir. It has a land area of 51 square-miles. The Spill Response Region, which is drawn as the ½-mile buffer area on either side of the channel, has an area of 18.7 square-miles. As noted above, the Spill Response Region extends only ½-mile upstream along tributaries into Hyalite Reservoir.

2.2.3 Contaminant Plume Travel Time

Surface water supplies are vulnerable to chemical liquids spilled directly into the water body. Assessment of the travel time for a contaminant plume to move downstream from a spill is useful for planning source water protection activities. An attempt was made here to provide information on a 15-gallon spill of a liquid with a density of 8 lbs/gallon. The stream flow at the time of the spill was set equal to the median flow (17 cfs for Sourdough Cr.; 36 cfs for Hyalite Cr.). This moderately low flow represents a condition when a spill could have a more serious impact due to the lower dilution factor in the stream. Gasoline spilled from a ruptured car fuel tank may be an example of this type of spill. Such a spill event could occur along Hyalite Creek as a result of a vehicle accident on the Hyalite Reservoir Road.

The formulas to estimate plume travel time and concentration were obtained from Fischer et. al. (1979). Worksheets detailing the calculations and the results are provided in Appendix C. Figures [2-10](#) through [2-12](#) provide graphs of the calculation output. The results shown should be considered generally accurate to within a factor of 5 (or higher). In other words, a result with a value of 50 could range from 10 to 250. This type of accuracy, or lack thereof, is common to predictions of contaminant transport in surface

water. Field measurements of contaminant transport during controlled experiments (in surface water) are normally accurate to only a factor of 2 (Fischer et al. 1979).

Figures [2-10](#) and [2-11](#) illustrate estimated travel times for spills in Sourdough and Hyalite Creeks, respectively. The x-axis is the distance the spill has traveled. It can also be considered the distance upstream from the source water intake to where the spill occurred. The y-axis represents travel time in minutes. Considering [Figure 2-10](#) for Sourdough Creek, a spill occurring at 1-mile upstream from the intake would first arrive at the intake in about 20-minutes. The maximum contaminant concentration would occur at about 28-minutes. The plume would be essentially past the intake by about 37-minutes.

The results on Figures [2-10](#) and [2-11](#) indicate a spill occurring within a few miles of an intake will require a rapid response in order to prevent entry into the water system. A highly coordinated response would be required to prevent entry of a spill even when the first arrival time was 60-minutes or longer (spill location beyond 3-miles from intake). It would generally not be possible to prevent spill entry for shorter travel times (spill within 3-miles from intake) without implementation of special facility design and/or operation procedures.

[Figure 12](#) displays calculation results for the maximum concentration of the plume as a function of distance downstream from where the spill occurred. The y-axis of this plot is the plume concentration in units of milligrams per liter (mg/L). It is the whole-liquid concentration. Thus, if gasoline were spilled, the graph estimates the concentration of gasoline in units of mg/L. It is a reasonable assumption that the plume has little variation in concentration across the stream and with depth, and that the concentrations shown on [Figure 2-12](#) would be measurable in the source water intake. The maximum concentration for a spill occurring at ¼-miles from an intake is about 120 mg/L. Maximum plume concentration declines moderately slowly with distance. For spills occurring at 6-miles from the intake, the maximum concentration remains at levels in excess of 20 mg/L.

2.3 Groundwater Delineation

2.3.1 Lyman Spring

This section describes the delineation of Source Water Protection Areas for Lyman Spring.

Overview

Lyman Spring is located in an area of fascinating geology, located at the southern end of the Bridger Mountains. This area was first studied in detail by McMannis (1952), who prepared geological maps and cross sections over the entire range in fulfillment of a Ph.D. Thesis at Princeton University. The work completed for this Thesis is particularly impressive given the equipment, base mapping (or lack thereof), and means of travel (i.e., foot) that were available. McMannis' work has been found generally accurate to the

present. More recent work on the structural geology of the Bridger Mountains has been completed by Lageson (1989), Professor of Geology at Montana State University. This work provides an excellent description of the structural history of the Bridger Mountains over the past 3 billion years. Custer (unpublished), also a Professor of Geology at Montana State University, has compiled geological maps for the Bridger Range and Gallatin Valley. He has created a GIS database of this information. The GIS data, which was invaluable to this project, was willingly provided by Dr. Custer.

Groundwater discharging from Lyman Spring first enters the ground on both the east and west sides of the Bridger Mountains. The groundwater on the east side of the range actually flows through a topographic ridge, which is a somewhat unique occurrence. It is possible that some groundwater discharging from Lyman Spring first enters the ground as far north as Saddle Peak.

Groundwater in the Bridger Mountains is recharged by precipitation onto the land surface. A substantial amount of this precipitation occurs as snow and forms the mountain snow pack. When snowmelt occurs and during heavy rain, some of the water seeps into the rocks forming the mountains and some forms surface water runoff, discharging into the local streams. It is expected that some of the surface water runoff also enters the ground where streams cross rocks that have large openings formed by fractures and caves. One of these formations that is noted to have such features is called the Madison.

The Madison is a rock formation of an ancient seabed. The rocks, referred to as limestone and dolomite, form striking gray cliffs throughout the area. This formation in places has large voids that formed when parts of the rock were dissolved. There is also intense fracturing present in the Bridger Mountains due to the mountain building process. In combination, the Madison has properties that make it a good groundwater reservoir. The Madison is presumed to be the most important formation related to the Lyman Spring discharge, but there are also other rock formations involved.

The direction of groundwater flow in the Bridger Mountains near to Lyman Spring is southerly, but can vary locally. A large fault runs up the Lyman Creek drainage to the summit of Baldy Mountain, acting as a collection "drain" for groundwater in the mountains. Groundwater can flow into the fault from either the east or west, and then flows southerly in the fault plane. The Lyman Spring discharge appears to occur directly from the fault plane at the headwaters of Lyman Creek.

Hydrogeologic Units

The geological section occurring in the Bridger Range includes rocks from Archean to Quaternary in age, a span of over 3 billion years. An excellent summary of these formations is provided in Appendix D. A hydrogeologic map (Custer unpublished) is provided on [Figure 2-13](#) and geological cross sections (by McMannis 1952) are provided

on [Figure 2-14](#). Table 2-1 provides a key for symbols used in the cross sections on [Figure 2-14](#).

TABLE 2-1FORMATION SYMBOLS

| Age | Symbol | Rock Type | Formation Names |
|------------------------------------|--------|----------------------|---------------------------------|
| Tertiary (< 65) | Tkl | Mudstone – Sandstone | Livingston Group |
| Cretaceous (65 – 136) | Kce | Mudstone – Sandstone | Colorado and Eagle |
| | Kc | Mudstone | Colorado |
| | Kk | Mudstone – Sandstone | Kootenai |
| Jurassic (136 – 195) | J | Mudstone – Sandstone | Morrison, Ellis Group |
| Permian – Pennsylvanian(225 – 320) | Paq | Mudstone – Sandstone | Amsden, Quadrant |
| Mississippian (320 – 345) | Mmc | Limestone – Dolomite | Madison Group – Mission Canyon |
| | Mlp | Limestone – Dolomite | Madison Group – Lodgepole |
| Devonian (345 – 395) | D | Mudstone – Limestone | Jefferson, Three Forks, Maywood |

| | | | |
|---|-----|----------------------|-------------------------|
| Cambrian (500 – 570) | C | Mudstone – Limestone | Snowy Range to Flathead |
| Precambrian (>2,000) | PCa | Metamorphic Gneiss | None designated |
| Ages are listed in units of millions of years before present. | | | |

The location of major aquifer units, as designated by Custer (unpublished), are mapped on [Figure 2-13](#). Structural data shown on this figure were digitized from the earlier work by McMannis (1952). The primary aquifer unit occurring above Lyman Spring is considered to be the Mission Canyon Formation of the Madison Group. These rocks, which are about 300 million years old, consist of marine limestone deposits. Permeability and porosity occurring in the formation is normally attributed to dissolution cavities, which are most common at the top of the unit (Roberts 1966). Dissolution of evaporite minerals, such as anhydrite, is speculated where solution breccias are observed in rock outcrops. In the Bridger Mountains, it is also likely that fractures, occurring in fault zones and as rock jointing, contribute significantly to the permeability. The Pennsylvanian Quadrant Quartzite and the Cretaceous Kootenai Formation may also be important aquifer units to Lyman Spring, and are included in the mapped aquifer units on [Figure 2-13](#).

[Figure 2-13](#) shows a fault running northeasterly from Lyman Spring to near the summit of Baldy Mountain. This fault, referred to here as the Lyman Spring Fault, appears to be the major conduit for groundwater discharge at the spring. It appears that this fault collects groundwater from the adjoining formations and transmits flow to the spring.

A small band of Mission Canyon and Quadrant Quartzite extends from Lyman Spring to the north. These aquifers are likely a contributor of groundwater to Lyman Spring. However, the majority of the surface outcropping of aquifer units exist to the east from Lyman Spring, on the east side of the Bridger Ridge. Aquitard units, as shown on [Figure 2-13](#) and [2-14](#), separate these major aquifers from the Lyman Spring Fault and Lyman Spring. Consequently, there must be a fracture flow connection that enables groundwater flow from the east-side aquifer units to the Lyman Spring Fault. [Figure 2-14](#) (Section B-B') shows the Lyman Spring Fault as a high-angle easterly dipping structure. There is most likely fractures that connect the aquifer units to this fault. The fractures may be

westerly dipping, subparallel to the fold axis of these strata. They may be vertical or sub-vertical with an east-west orientation. They may also be westerly dipping and related to normal faults on the west side of the Bridger Range.

Structural History

The structural history of the Bridger Mountains is summarized here based on the work by Lageson (1989) and Skipp et al. (1999). This technical information was contemplated in determining the Lyman Spring Source Water Protection Areas. It is documented here for future reference and those interested in a structural overview of the Bridger Mountains.

Event 1: During late Proterozoic time (~1.5 billion years ago), east-west oriented normal faulting occurred. The Proterozoic Belt Supergroup Lahood Formation was deposited north of Ross Pass. Today these rocks occur only north of Ross Pass. To the south of Ross Pass much older Archean gneiss is present. Erosion of the Archean gneiss occurred to form the Lahood Formation deposit, which is a conglomerate near to the fault and transitions to deep lake beds farther to the north.

Event 2: About 55 to 60 million years ago, compressional stresses thrust rocks easterly (Sevier orogeny). Thin-skinned thrusting occurred along new thrusts, but also along reactivated Precambrian faults, such as the Pass Fault occurring at Ross Pass. This thrusting can be seen most clearly in the Fairy Lake area of the range, but it has been dramatically influenced by later compression (see below).

Event 3: About 50 to 55 million years ago, a larger compressional event occurred, resulting in deep-seated thrusting (Laramide orogeny). The deep seated thrusting did not have a large associated translation, but it exposed the older basement rocks of Archean and Proterozoic age. In the Bridger Mountains, a large basement uplift occurred that resulted in severe folding of the Paleozoic section (younger rocks, such as the Madison Group). These rocks were overturned in places and generally have very steep easterly dip elsewhere on the east side of the Bridger Ridge. Fault structures formed during the Sevier Orogeny (above) also were folded. The major thrust fault that caused the uplift does not penetrate to land surface, and is referred to as the Sub-Bridger Thrust Zone. It has been mapped based on subsurface exploration data.

Event 4: In the time span from about 15 to 25 million years ago, the Bridger Mountains were subjected to crustal extension. This structural event occurring in the Bridger range is considered to be the northerly extent of the Basin and Range structural province, which occupies most of Nevada. The Range Front Fault of the Bridger's (westerly fault on [Figure 2-13](#) and shown on west side of sections on [Figure 2-14](#)) was formed. This fault, which has other associated faults, is a major structure that apparently truncated the

western half of the Bridger Mountains. The west half of the range was displaced westerly and downward relative to the existing east half of the range (only the east half of the range is presently visible). The west half of the range is now buried beneath the Gallatin Valley. It is estimated that perhaps 7,000 feet of sediment has been deposited in the valley on top of the former west half of the Bridger Mountains.

Lyman Spring Discharge

Stream flow data for Lyman Creek were available for the period from 1951 to 1953. These data were collected at a temporary gauging station below the city of Bozeman intakes. The data were obtained from the U.S. Geological Survey website, as noted above.

[Figure 2-15](#) presents a hydrograph of stream flow for the period of record. Peak flow in the stream was 18 cfs occurring during July 1952. Low flow ranged from 2 to 3 cfs and occurred during late winter. For the purposes of this study, it was assumed that all discharge in Lyman Creek was spring discharge. This assumption is valid during most of the year, however, it is likely that a surface runoff component exists during spring (particularly given the large variation in discharge through the year). The quantity of water used by the city of Bozeman and any other losses upstream from the gauge have not been evaluated. Total discharge in the creek averaged 4,026 acre-feet during the 1951 – 1953 monitoring period.

Groundwater Recharge

Water balance calculations were made for the Bridger Mountains in order to estimate groundwater recharge to the aquifers of this area. Appendix E presents a calculation worksheet. Input data consisted of precipitation and temperature data for the Bozeman area. Precipitation was multiplied by an assumed factor of 1.5 to account for higher precipitation in the Bridger Mountains. Runoff was set equal to 10% of the precipitation for undeveloped terrain. Evapotranspiration was computed according to the Thornthwaite Method (Gupta 1989). Deep percolation, or groundwater recharge, was computed using monthly values for the water balance and while accounting for soil moisture. A groundwater recharge rate of 6 inches/year was estimated. Based on the spring discharge of 4,026 acre-feet (above), the land area contributing recharge to Lyman Spring is estimated at 12.6 square-miles.

Groundwater Flow Direction

Lyman Spring is located at the southern end of the Bridger Mountains at an elevation of approximately 5,600 feet. Land areas to the west and south are at lower elevation than the spring. Consequently, groundwater recharge must occur from the area to the north and

east. Groundwater flow direction to the spring is anticipated to be southerly toward the Lyman Spring Fault (Figures [2-13](#) and [2-14](#)). Locally, groundwater flow into the fault zone may be easterly or westerly, however, the net flow to the spring occurs from north to south.

Lyman Spring Delineation

Source Water Protection Areas for Lyman Spring are presented on [Figure 2-16](#). The Recharge Area of 13.5 square-miles extends north to Saddle Peak. This area is slightly larger than the estimated recharge area to Lyman Spring (12.6 square-miles). The Recharge Area was estimated to be approximately centered on the Bridger Ridge and to include only land areas at elevations greater than 5,600 feet, the elevation of the spring. The Inventory Region, also shown on [Figure 2-16](#), has an area of 7.5 square-miles. It is located to include all major aquifer units with surface outcrops inside of the Recharge Area. There is an approximately 500 ft to 1,000 ft buffer applied to the Inventory Region. Aquitard formations located between aquifers also have been included within the Inventory Region.

3 CONTAMINANT SOURCE INVENTORY

This section inventories potential and existing contaminant sources that may impact source water quality in Sourdough and Hyalite Creeks and at Lyman Spring. The city of Bozeman watersheds occur primarily in rural federal lands that are non-commercial and have limited agricultural use. Consequently, contaminant sources that are typical of urban and agricultural areas, such as gasoline storage tanks, commercial facilities, croplands, and feed lots, are not present.

The following types of potential contaminant sources *do not exist* in the city of Bozeman watersheds:

- ▶ Point sources of hazardous chemicals (e.g., solvents, hydrocarbon fuels)
- ▶ Storm water discharge outfalls
- ▶ Moderate to high densities of septic systems

- ▶ Sewer collection systems and wastewater effluent outfalls
- ▶ Cropped agricultural lands and feed lots
- ▶ Pipelines and major transportation corridors

It may be a reasonable assumption that these types of sources will not exist in the future, for at least the next 20 to 50 years. Continued absence of these land uses from the watersheds should be one of the most important source water protection activities pursued by the city of Bozeman.

This SWDAR focuses on the types of sources that may be important in the city of Bozeman watersheds, which are summarized in Table 3-1. Additional information regarding these sources is provided in the remainder of this section. This information is presented based on a review of existing data sources, consisting of maps and published reports. The quality of the information presented here can be no better than the quality of the reference materials. The Contaminant Source Inventory should be updated annually, including a review of new reference materials, when available, and periodic field surveys of the watersheds.

TABLE 3-1

POTENTIAL CONTAMINANT SOURCES

| Potential Contamination Source | Type of Contaminant |
|--------------------------------------|---------------------------|
| Forest access (paved, unpaved roads) | Sediment, petroleum fuels |
| Forest fires | Sediment, ash |
| Livestock grazing | Sediment, pathogens |

| | |
|-------------------|--|
| Mining | Trace metals, petroleum fuels, sediment |
| Oil and gas | Petroleum product, drilling fluids, sediment |
| Recreation | Sediment, petroleum fuels, pathogens |
| Timber harvesting | Sediment, petroleum fuels |
| Wildlife habitat | Pathogens |

3.1 Inventory Methods

This contaminant source inventory was completed primarily by contacting individuals at the U.S. Forest Service in Bozeman who work on the Gallatin National Forest. Information was obtained from these individuals in the form of GIS data files, reports, and personal communication (USFS 2000). Land section data that was used to focus these information sources is shown on [Figure 3-1](#). Digital images of air-photos were also obtained for the watershed areas. The photos were plotted in the watershed areas and the Source Water Protection Areas were overlaid onto the maps. These air-photo maps, which are presented on large sheets, can be viewed at the city of Bozeman. Land use data for the watersheds was also obtained from the state of Montana Natural Resources Information System (NRIS) by downloading from the state's website (<http://nr.is.state.mt.us>). The land use data were actually prepared by the U.S. Geological Survey (USGS).

3.2 USGS Land Use Designations

The U.S. Geological Survey (USGS) has produced maps of the United States showing present land use. The maps exist at a scale of 1:100,000. Their origin is not well documented, however, they were likely developed by processing air-photos, which may be from the 1980s to early 1990s. Electronic copies of the maps for the Bozeman area were accessed from the state of Montana NRIS website.

[Figure 3-2](#) presents USGS land use designations for the city of Bozeman watersheds. All land areas above the source water intakes are designated as open land use. Open lands provide the greatest degree of natural protection to either surface or ground waters. There are no urban, cropped agriculture, feed lots, or mining land uses within the watersheds. The absence of these land uses is highly favorable for source water protection.

Open lands are susceptible to wild fires, either naturally- or human-started. Wild fire is a significant threat to water quality in the Sourdough and Hyalite Creek watersheds. Extensive fires in these areas could result in high sediment loadings to the stream channels, as well as ash deposition. It is likely the city would shut down intakes under certain conditions related to wild fires. The Lyman Spring water supply will be protected from wild fire because it is a groundwater source. However, it is conceivable that the fractured carbonate bedrock aquifer of this source could show some increase in turbidity in the years following a major wild fire.

The main access road along Hyalite Creek would be considered a transportation land use, however, it is not identified in the USGS land use maps, likely due to its small size. Transportation land uses pose a threat to water quality by the potential for vehicle accidents and associated fuel spills. The history on Hyalite Creek has shown that accidents into the creek and associated spills have not affected the city's use of water. Future increases in recreation will result in higher vehicle numbers and greater probability for a major accident into the stream channel.

3.3 Land Ownership & Jurisdiction

Land ownership in the city of Bozeman watersheds is shown on [Figure 3-3](#). These data were obtained from the U.S. Forest Service (USFS) in GIS format. The city of Bozeman owned land at Lyman Spring is not shaded because it exists outside of Gallatin National Forest.

The largest land owner in the city of Bozeman watersheds is the federal government, and these lands are managed by the USFS. All federal lands in the city of Bozeman watersheds are within Gallatin National Forest (GNF). Gallatin National Forest is managed by five Ranger Districts and a Forest Supervisor's Office. The city of Bozeman watersheds are located within the area managed by the Bozeman Ranger District (406-522-2520, USDA Building). GNF planning, which also includes the area of the city's watersheds, is completed by the Forest Supervisor's Office (406-587-6701, Federal Building).

Privately owned land in the city of Bozeman watersheds exists along the watershed boundaries and in the interior. On [Figure 3-3](#), shading is used to show the location of privately owned lands, owned by the city of Bozeman, that are located inside of Gallatin

National Forest. The city of Bozeman is the only private land owner with parcels inside of the GNF boundary. Unshaded areas of private land shown on [Figure 3-3](#) in the watersheds are outside of the GNF boundary.

The city of Bozeman parcels inside of Gallatin National Forest include about 6.5 sections of land in the Sourdough Creek watershed. The intake on Sourdough Creek is located on city-owned lands. The city of Bozeman also owns land at Lyman Spring, which is not shaded on [Figure 3-3](#) because it is located outside of the GNF boundary. The city of Bozeman does not have any land ownership in the Hyalite Creek watershed. The Hyalite Creek intake is located on the federally owned lands of Gallatin National Forest.

The federal government has jurisdiction over all federally owned lands, which includes any lands designated as Gallatin National Forest. Privately-owned parcels in the watersheds are within Gallatin County, outside of the city of Bozeman limits. These parcels are governed by Gallatin County and the state of Montana, even when owned by the city of Bozeman.

The city of Bozeman has limited potential to develop rules and regulations in any of the watersheds independently of the federal government, Gallatin County, and the state of Montana. There are several Montana Codes that may be pursued and provide the city some ability to regulate for source water protection purposes beyond the city limits (DEQ 1999, Table 7). These Montana Codes include, for example:

- ▶ 7-4-4306 MCA: The mayor may exercise such power vested by ordinance to enforce public health ordinances and regulations in all places within 5 miles of the city limits;
- ▶ 7-21-4204 MCA: The city or town has the power, within the city or within 3 miles, to regulate any offensive and unwholesome establishments;
- ▶ 7-33-4205 MCA: The city or town has the power to regulate and prevent the storage of kerosene, oils and inflammable materials within 3 miles of the city limits.

The lack of jurisdiction by the city of Bozeman in the watershed areas is undesirable in terms of source water protection. It is preferable for a water system to have the ability to make rules for source water protection, should it be decided that new rules are needed. The lack of jurisdiction is not necessarily detrimental, as the other governing bodies will be interested to assist the city in protection of a municipal water supply, and water quality standards exist that must be met on these lands.

There is potential, however, for the other governing bodies to possibly overlook the city of Bozeman interests in these watersheds. For this reason, the city of Bozeman should establish direct communication with the governing bodies with the specific purpose of source water protection. The city should meet with each governing body on a regular basis to learn about activities occurring in the watershed areas, and to provide comments where applicable.

3.4 Gallatin Forest Plan

The Gallatin Forest Plan (GFP) was published in the mid-1980s (USDA-FS ca. 1987), and describes the intended management of the forest extending to the year 2035. The GFP will be updated in three to five years. This section uses information from the GFP in the city of Bozeman watersheds. Copies of the GFP may be obtained or borrowed from the Forest Supervisor's Office in Bozeman (P.O. Box 130, Bozeman, MT 59771).

3.4.1 Water Quality

The GFP begins with statements of goals and objectives. One of the goals is to protect water quality to meet or exceed state of Montana standards. There are three corresponding objectives to this goal under a subsection entitled *Water and Soils*.

Objectives – Water and Soils

- ▶ Municipal watersheds will be managed to meet State water quality standards.
- ▶ Watersheds will be managed by application of "best management practices". Management standards have been set to mitigate impacts occurring to the watershed resource from land use activities.
- ▶ In drainages with intermingled ownership, the Forest Service will work closely with the private landowners to develop watershed objectives and, where necessary, schedule management activities to ensure the desired condition of the watershed is maintained.

The GFP also includes a section of *Forest-Wide Standards*, which are to be met by projects and developments occurring in Gallatin National Forest. Several standards are listed within a subsection entitled *Water and Soils*, and are outlined below.

Forest-Wide Standards – Water and Soils

- ▶ The Forest Soil Survey will be incorporated into resource area analysis.
- ▶ Best management practices (BMPs) will be used on all Forest watersheds in the planning and implementation of project activities.
- ▶ Require a watershed cumulative effects feasibility analysis of projects involving significant vegetation removal.
- ▶ Sufficient amounts of water necessary to carry out Forest operations will be claimed in accordance with State water rights law.
- ▶ Comply with Executive Order 11990 (Protection of Wetlands) and Forest Service policy in FSM 2500.
- ▶ Water transmission or storage facilities and hydro-meteorological data sites will be maintained in safe and serviceable condition.
- ▶ Applications for hydropower, water diversion, water storage, or other water-related facilities will be evaluated on a case-by-case basis and coordinated with other agencies when appropriate.
- ▶ All management practices will be designed or modified as necessary to maintain land productivity and protect beneficial uses.
- ▶ In watersheds with intermingled land ownership, efforts will be made to develop mutually agreeable watershed management direction.
- ▶ In municipal watersheds, such as Bozeman, Hyalite and Lyman Creek drainages, all project activities will be implemented to ensure State water quality standards are met. Coordination with City of Bozeman officials and the State Water Quality Bureau will be done throughout the project planning process."

The objectives and standards listed above indicate the Forest Service will manage Gallatin National Forest in a manner that is protective of water quality. This requirement of the GFP is a substantial benefit to the city of Bozeman. It provides a basis for forest management that should sustain a high-quality water supply into the future.

The last standard listed above pertains directly to the city of Bozeman watersheds, indicating that by adoption of the GFP, the Forest Service has committed to a coordination relationship with the city of Bozeman. It appears at this time that if a project were to be proposed in the city's watersheds, *and* the Forest Service considered it may have an effect on water quality, the city of Bozeman would be notified and allowed to participate in the project review.

In terms of source water protection planning, it is preferable that the city of Bozeman be proactive, and regularly meet with the Forest Service (e.g., annually) to discuss projects that may be planned in the watersheds. This approach will in general be more effective than the approach of waiting to be notified by the Forest Service, and should reduce the potential for surprises.

The objectives and standards also refer to Best Management Practices (BMPs), as a means to protect water quality. The GFP, however, does not specify the BMPs. It is conceivable that application of BMPs for a project may in some cases fall short of providing adequate protection of water quality. These inadequacies must be evaluated on a case-by-case basis. The city of Bozeman will need to review the specific BMPs that would be implemented on critical projects occurring in the city's watersheds.

3.4.2 Management Areas

The GFP designates management areas to the land of Gallatin National Forest. Each management area emphasizes a particular management direction. Figures [3-4](#) and [3-5](#) present the management areas in the Hyalite and Sourdough watersheds, and in the Lyman Spring recharge area, respectively. Table 3-2 summarizes the description of each management area (management areas occurring outside of the city watersheds are not described). Appendix F provides the GFP text for each management area that appears in Table 3-2.

Sourdough Creek Watershed

The majority of the Sourdough Creek watershed is designated as management area MA-12, as shown on [Figure 3-4](#). MA-12 is a habitat and recreation management area. A large riparian protected zone, MA-7, is mapped along the Sourdough Creek channel. MA-9 and MA-11, which both allow for timber harvest, are designated to relatively small areas in the watershed. MA-9 is designated to

about 1,310 acres, or 6% of the total area (21,031 acres). MA-11 is designated to only 720 acres, or 3% of the watershed. The location of the MA-9 land area, however, is relatively near to the city of Bozeman intake, which may be undesirable depending on access routes.

Several sections of land are designated as management area MA-99, indicating they are private lands or have not been assigned a management direction. Most of these land sections are owned by the city of Bozeman (cf. with [Figure 3-3](#)), or have been recently acquired by the Forest Service through land swaps.

Hyalite Creek Watershed

As [Figure 3-4](#) shows, there are a variety of management area designations in the Hyalite Creek watershed. MA-5 is the main travel corridor and includes the paved road along the Hyalite Creek channel. This management area comprises 23% of the watershed. It can include timber harvest, but such harvesting would be limited only to increase wildlife habitat. A riparian protected zone, designated as MA-7, exists along Hyalite Creek, but is not shown on the map because of its narrow width.

Management designations MA-8, MA-9, and MA-11, which allow for timber harvest, are assigned to approximately 9,983 acres in the watershed, which constitutes 54% of the total land area (18,488 acres). MA-8 designated areas are considered the most valuable in terms of timber harvest and constitute 4,640 acres of the watershed, or 25%. No timber harvest has occurred in the Hyalite Creek watershed during the GFP planning period, nor are there any current proposals for timber harvest. It is possible that timber harvests in the watershed could be significant at some future time.

Several sections of land in the Hyalite Creek watershed are designated as management area MA-99. These sections were formerly private properties, but have been acquired by the Forest Service through land swaps. They will be assigned management directions when the GFP is updated.

Lyman Spring Recharge Area

The management area designations for the Lyman Spring recharge area are shown on [Figure 3-5](#). Most of the recharge area is designated MA-12, which is a habitat and recreation management direction. There is a small area designated MA-11, which can allow for timber harvest. A slightly larger area is designated MA-17, which is considered valuable for livestock grazing and wildlife habitat.

TABLE 3-2 (page 1 of 3)

GALLATIN FOREST PLAN MANAGEMENT AREAS

| Management Area | General Description | Goals |
|-----------------|---|--|
| MA-1 | These areas include developed campgrounds, picnic areas, boat ramps, and visitor information sites, plus potential developed sites. | <ol style="list-style-type: none"> 1. Maintain these sites and facilities for the safety and enjoyment of users. 2. Provide additional facilities where analysis shows the need. |
| MA-3 | These areas consist of nonforest, noncommercial forest, and forested areas that are unsuitable for timber production. | <ol style="list-style-type: none"> 1. Managed essentially in their present condition to protect existing improvements and resources, with minimal investment for resource activities. |
| MA-5 | These areas are travel corridors that receive heavy recreation use. | <ol style="list-style-type: none"> 1. Maintain and improve the wildlife habitat values and the natural attractiveness of these areas. 2. Allow a level of timber harvest consistent with goal 1. |
| MA-7 | These areas are riparian management | <ol style="list-style-type: none"> 1. Manage the riparian resource to protect |

| | | |
|-------------|--|---|
| | <p>areas, and exist along all waterways in Gallatin National Forest. Many of these areas are small in size and are not shown on the management area map.</p> | <p>the soil, water, vegetation, fish and wildlife dependent upon it.</p> |
| <p>MA-8</p> | <p>These areas consist of lands that are suitable for timber management.</p> | <ol style="list-style-type: none"> 1. Provide for productive timber stands and optimize timber growing potential. 2. Develop equal distribution of age classes to optimize sustained timber production and improve vegetative diversity. 3. Allow for other resource uses if compatible with goals 1 and 2. 4. Meet State water quality standards and maintain channel stability. |

TABLE 3-2 (page 2 of 3)

GALLATIN NATIONAL FOREST MANAGEMENT AREAS

| Management Area | General Description | Goals |
|-----------------|---|---|
| MA-9 | These areas consist of suitable timber lands that have high dispersed recreation value and are visually sensitive. | <ol style="list-style-type: none"> 1. Provide for a variety of dispersed recreation activities in a roaded setting. 2. Harvest timber consistent with goal 1. 3. Meet State water quality standards and maintain channel stability. |
| MA-11 | These areas consist of forested big game habitat. They include productive forest lands that are available for timber harvest. | <ol style="list-style-type: none"> 1. Maintain elk habitat effectiveness following timber harvest. 2. Base vegetative management on vegetation that is needed for wildlife target species. 3. Allow a level of timber harvest consistent with goals 1 and 2. 4. Meet State water quality standards and maintain stream stability. |
| MA-12 | These areas provide important habitat for wildlife and also offer dispersed recreation opportunities. | <ol style="list-style-type: none"> 1. Maintain and improve vegetative condition to provide habitat for a diversity of wildlife species. 2. Provide for a variety of dispersed |

| | | |
|-------|---|---|
| | | <p>recreation opportunities.</p> <p>3. Provide forage for livestock consistent with goal 1.</p> |
| MA-16 | <p>These areas have open grasslands interspersed with nonproductive timber lands. They contain the most productive and heavily used portions of range allotments.</p> | <p>1. Maintain or improve vegetative conditions and forage production for livestock use.</p> |
| MA-17 | <p>These areas are grasslands or nonproductive forestlands on slopes of less than 40% that are suitable for livestock grazing and contain important big game habitat.</p> | <p>1. Maintain or improve vegetative conditions and forage production for livestock and wildlife use.</p> |

TABLE 3-2 (page 3 of 3)

GALLATIN NATIONAL FOREST MANAGEMENT AREAS

| Management Area | General Description | Goals |
|-----------------|---|--|
| MA-18 | These areas consist of high mountain peaks and cirques in the northern portion of the Hyalite-Porcupine-Buffalo Horn Study Area. | <ol style="list-style-type: none">1. Emphasize dispersed recreation use and protect scenic qualities.2. Maintain and enhance bighorn sheep habitat. |
| MA-21 | These areas are proposed Research Natural Areas. | <ol style="list-style-type: none">1. Provide areas for non-manipulative research, observation, and study of undisturbed ecosystems. |
| MA-99 | These areas do not presently have a management direction assigned. They are private lands within GNF, or lands acquired by USFS through land swaps. | No goals exist for these land areas. |

3.5 Livestock Grazing

Livestock grazing by permit from the Forest Service is allowed in selected areas, referred to as grazing allotments. Grazing allotments that occur inside of the city of Bozeman watersheds are shown on [Figure 3-6](#). One allotment is present in Hyalite Creek and two are present in the Lyman Spring recharge area. There are no allotments that occur in the Sourdough Creek watershed, other than the slight overlap which is shown on [Figure 3-6](#).

The Hyalite Canyon allotment has two separate parts and includes three pastures that are used on a rotating schedule. A total of 90 cow/calf pairs are planned for this allotment. Grazing may occur from July 5 to October 6 annually. Cattle are prevented from access to streams, including the Hyalite Creek channel, by natural barriers and fences. An environmental assessment (EA) was prepared to evaluate the potential for impacts related to this grazing allotment (USFS 1997). Based on the EA, a determination of non-significance was made, which is included in Appendix G. The EA specifically addresses the city of Bozeman water supply from Hyalite Creek (page Appendix C – 9). It was found that because the livestock are not allowed to access the creek and are not allowed to concentrate that no changes to the natural quality of the water will occur, and therefore, the city water supply will not realize any differences in water quality as a result of livestock grazing in the area.

Because cattle can move into areas outside of the allotments and are a potential carrier of human pathogens, the city of Bozeman should consider periodically monitoring grazing use in the Hyalite Creek watershed. If the city were to find cattle had moved into areas outside of the grazing allotments, and in particular, areas where cattle could directly access stream channels, the city could notify the Forest Service to take appropriate actions.

The two allotments shown in the Lyman Spring recharge area are named West Bridger and Pine Creek. West Bridger is grazed annually from July 1 to October 1 with 40 cow/calf pairs. Pine Creek is grazed annually between July 1 and September 30 with 46 cow/calf pairs. These cattle numbers are allowed under the present permit. The numbers could go up or down after a permit renewal. No special documents were identified for these areas to assess potential impacts. A copy of the permit that is issued to the livestock producer, and which includes terms and conditions, is provided in Appendix G. Both allotments are distant from the Lyman Spring intake. It is anticipated that water quality impacts from cattle would be indistinguishable from the natural quality of water obtained from Lyman Spring.

3.6 Mining, Oil and Gas Development

3.6.1 Mining

Explorations were made for extraction of lead (mineral galena) in the Hyalite Creek watershed beginning in about the 1960s. The activity was referred to as the Langhor Lead

Mine by the Forest Service and it is believed to be rehabilitated, as of 1990. The activity is referred to as The Sunshine Mine in the state of Montana Mine Waste Cleanup Bureau Hard Rock Inventory (PA 16-102). The state considers this site low priority and has no further investigations planned. The location of this abandoned mining operation is shown on [Figure 3-7](#). It consisted of a single shaft and drift. It is believed that no ore was ever extracted from the property. The shaft and drift have been filled and cannot be accessed from the surface.

There are presently no mining claims in any of the city of Bozeman watersheds. However, there are no laws or restrictions that prevent new mining claims from being filed. The filing party will need to comply with rules and regulations that include provisions for water quality protection. The Forest Service would be required to prepare an Environmental Assessment (EA) for the claim and possibly an Environmental Impact Statement (EIS). Any mineral extraction would require a major EIS to be prepared.

If a mine were to open in the city of Bozeman watersheds, it would pose a significant threat to water quality. This threat is likely to occur regardless of water quality protection measures built into the project. Even modern mining activities have resulted in deterioration of local water quality. Although exceptions exist, few mining operations have occurred in which water quality of the area was not impacted to some degree.

3.6.2 Oil and Gas

Oil and gas leases exist on Gallatin National Forest land in the Sourdough Creek watershed and in the Lyman Spring recharge area. Land sections that include any acreage which has been leased for oil and gas development are shown on [Figure 3-7](#). These leases were established in the early 1980s related to an "oil boom". They have been put on a "suspended status" by the Ninth Circuit Court of Appeals. It is most likely that production will not occur in these areas due to limited petroleum resources.

Exploration for coalbed methane gas is planned near to Bozeman. The target formation for this development is the Cretaceous Eagle Sandstone, which includes the coal beds of the Livingston coal fields. The Eagle Sandstone is not mapped in the Sourdough Creek watershed or the Lyman Spring recharge area (Roberts 1972). Therefore, coalbed methane development is not anticipated in these areas.

3.7 Timber Harvest

The Forest Service identifies selected parcels to allow timber harvest. Developers are allowed to bid on the selected parcels periodically, and to log the area according to terms and conditions set forth by the Forest Service. The terms and conditions include elements to protect water quality and must comply with the Forest-Wide Standards of the Gallatin Forest Plan. Portions of the contract language that are used for timber harvest are provided in Appendix H.

There has been no timber harvest in the city of Bozeman watersheds since the preparation of the Gallatin Forest Plan (GFP) in 1987. There are no proposals that exist to make timber harvest available in these areas. It is possible and likely that timber harvest will occur at some future time, although the heavy recreation use of these areas will affect Forest Service decisions. High recreation use will tend to displace timber harvest in these areas. Those land areas with a management direction including timber harvest are shown on Figures [3-4](#) and [3-5](#).

The GFP indicates that the maximum parcel size for timber harvest is 40 acres. Timber harvest may occur in areas from about 1 acre up to this maximum size. Clear cutting, as occurred years ago, is not practiced. Modern harvest methods would typically allow for cutting up to 75% of a stand. The remaining 25% of the trees would be left in clusters and as isolated trees. Developers would be required to comply with rules pertaining to spill control, erosion, water quality, and regeneration of the harvested area.

It is unlikely but possible that developers can apply pesticides and herbicides to harvest areas. Forest Service personnel indicate these applications are remote at best. However, the Gallatin Forest Plan lists herbicides as a method for site preparation and the use of pesticides during site regeneration.

Transport of logging equipment, fuels, and chemicals (if any) into the watersheds may have a greater chance for impacting the city of Bozeman water quality than the actual timber harvest. Accidents resulting in spills directly into the stream channel could occur, which may have an immediate impact on the city's water quality. The city of Bozeman will benefit by periodically meeting with the Forest Service to learn about and comment on any timber harvest proposals in the watersheds.

4. SUSCEPTIBILITY ASSESSMENT

The state of Montana has developed a method to determine the susceptibility of a source water intake to be contaminated by a given potential source of contamination. For example, the method would determine the susceptibility of a source water intake to be contaminated by a gasoline storage tank located near to the intake. The susceptibility categories that may be assigned include very-low, low, moderate, high, and very-high. Very low susceptibility indicates that a potential contaminant source has little chance of contaminating a source water intake. In contrast, very-high susceptibility indicates that a potential contaminant source has a likely chance of contaminating a source water intake. The actual risk, as a quantified probability to contaminate the source water intake, is not determined by this method. The method results are qualitative and are intended for use in prioritizing management activities.

4.1 Method Summary

Susceptibility assignments (to a source water intake) are made for each significant potential contaminant source identified in the source inventory, including point and non-point sources. The method is conservative, resulting in generally high susceptibilities even when a quantified risk of contamination may be very low. Some of the conservative nature of the method is eliminated by only applying the method to significant potential sources of contamination. Significant potential contaminant sources that are normally considered in a susceptibility assessment include the following:

- ▶ Septic systems
- ▶ Animal feeding operations
- ▶ Underground storage tanks
- ▶ Leaking underground storage tanks
- ▶ State and federal superfund sites
- ▶ RCRA large quantity generators
- ▶ Underground injection wells
- ▶ Wastewater treatment / spray irrigation / lagoons
- ▶ Landfills
- ▶ Abandoned mines
- ▶ MPDES wastewater discharges
- ▶ Municipal sanitary sewers
- ▶ Municipal storm sewers
- ▶ Storm water discharges
- ▶ Highways, railroads and pipelines
- ▶ Cultivated cropland

There are two steps to determining susceptibility. First, the potential contaminant source is assigned a hazard level, based simply on its occurrence within a source water protection area. Hazard levels are categorized as low, moderate, and high. Those sources that are nearest to a source water intake (or occupy a large land area) will have a higher hazard classification than sources that are farther away (or occupy a small land area).

In step two, the occurrence of barriers, either natural or engineered, that may protect the water source intake from the potential contaminant source are evaluated. A low permeability clay layer above an aquifer is an example of a natural barrier. A leak detection system for a buried tank is an example of an engineered barrier. If there are no barriers then little protection exists to prevent contamination of water in the event of a spill or leak. In these cases, the susceptibility assignment would be into a higher level, reflecting the absence of barriers. If one or more barriers are present, a spill or leak is likely to be captured or impeded. The presence of one or more barriers will tend to reduce the susceptibility level. Once the hazard level and number of barriers has been determined for each potential contaminant source, a susceptibility level can be determined. Table 3-3 summarizes the susceptibility categories with respect to the hazard level and the existence of barriers.

TABLE 3-3

SUSCEPTIBILITY CATEGORIES

| Presence of Barriers | Hazard Level | | |
|----------------------|--------------|----------|----------|
| | High | Moderate | Low |
| No Barriers | Very High | High | Moderate |
| One Barrier | High | Moderate | Low |
| Two or more Barriers | Moderate | Low | Very Low |

Table entries are the susceptibility (to be contaminated) of a water source intake to a specified potential contaminant source. The susceptibility level is determined based on the hazard level of the potential contaminant source and the number of barriers that exist to protect the water source from contamination.

4.2 Source Water Susceptibilities

The city of Bozeman watersheds are devoid of significant potential sources of contamination, with the exception of the main transportation corridor along Hyalite Creek.

Because the Langhor Lead Mine is not a priority abandoned mine site and appears to have been rehabilitated, it is not included in the susceptibility analysis. The road along Sourdough Creek also is excluded because it is closed to transportation using motorized vehicles. If this road were opened to commercial or public vehicles, the same susceptibility would be determined as for the Hyalite Creek Road. Livestock grazing in the watersheds is much more diffuse than a confined animal feeding area, and consequently, it also has been omitted from the susceptibility assessment.

Future land use in the watersheds could include significant potential sources of contamination, however, these sources cannot be evaluated until they occur. Mining, timber harvest, and livestock grazing are the most likely types of land uses that may occur in the future. Depending on the location of these land uses, they may or may not be considered significant potential contamination sources.

Hyalite Creek Road (FS #62)

The Hyalite Creek source water intake has a very-high susceptibility (to be contaminated) by transportation of chemicals, including vehicle fuels, on Hyalite Creek Road.

Hazard Level

Hyalite Creek Road occurs within the spill response region of the Hyalite Creek source water intake. Based on this location, Hyalite Creek Road is assigned a **high hazard level**.

Barriers

There are **no natural or engineered barriers** that protect the stream channel from contamination sources on Hyalite Creek Road.

Susceptibility

Using Table 3-3, the Hyalite Creek source water intake has a **very-high susceptibility** to sources of contamination on Hyalite Creek Road.

5. CONCLUSIONS

- ▶ The city of Bozeman watersheds are provided a significant degree of natural protection because they are located in rural lands. The urban land uses that have

historically resulted in contamination of water supplies are absent from the city watersheds at this time.

- ▶ Management of Gallatin National Forest by the U.S. Forest Service is a highly beneficial assistance to the city of Bozeman. Forest Service management is more stringent than occurs on private lands, and is more open to public comment. The Forest Service is directly concerned with protection of natural resources, and has identified the city of Bozeman water supplies in the Gallatin Forest Plan.

- ▶ Both the Hyalite and Sourdough intakes are susceptible to impacts from wild fires. Extensive fires in these areas could result in high sediment and ash loadings to the water supply. The city may choose to temporarily shut down one or both intakes in relation to wild fires in the area. Lyman Spring being a groundwater source, is much less susceptible to impacts from wild fire.

- ▶ Surface water supplies, such as Sourdough and Hyalite Creeks, are susceptible to contamination from spills. Neither of these source water intakes is designed with protection from chemicals that enter the stream channel. It will be beneficial for the city to consider spill protection when designing improvements to these intakes.

- ▶ The Hyalite Creek source water intake is the most susceptible (of the city's water sources) to contamination because of motorized vehicle transportation on Hyalite Creek Road, which is immediately adjacent to the stream channel.

- ▶ Livestock grazing in the watersheds does not appear to pose a significant threat of contamination. Livestock presence is not anticipated to change water quality from the natural water quality of the area. Cattle are prevented from concentrating along stream channels by natural barriers and fencing.

- ▶ There are no mining claims or active mines in the city of Bozeman watersheds. Mining does not pose a risk to water quality at the present time. If mining is allowed at some future time, a significant risk to water quality may occur. It is likely that a future mine in the city of Bozeman watersheds has the greatest potential for water quality impacts of any other potential contaminant source.

- ▶ Development of oil and gas in the city watersheds is unlikely given the geology of these areas. If oil and gas were developed, potential impacts to water quality may occur, but it should generally be feasible to protect water quality.

- ▶ Timber harvest presently does not occur in the city of Bozeman watersheds, and therefore poses no threat to water quality at this time. Future timber harvest is a possibility. It is most likely that transportation to and from harvest areas will pose a greater risk to water quality than the actual harvesting of trees. This risk will exist only if the transportation route is along the main stream channel or tributaries that flow to the source water intake.

6. RECOMMENDATIONS

Source Water Protection Plan

The next step in source water protection planning is to prepare a Source Water Protection Plan (SWPP). The SWPP incorporates this Source Water Delineation and Assessment Report (SWDAR), and three additional sections: 1) Contingency Planning; 2) Alternative Water Sources; and 3) Management Planning.

- ▶ A contingency plan documents the city's response to losses in water capacity due to contamination (or other events, such as earthquakes). Emergency water sources and procedures are identified in the contingency plan.

- ▶ Information pertaining to alternative water sources focuses on long-term source replacement. Should the city be required to develop a new source of water due to contamination (or other reasons), this section of the SWPP outlines the most likely new sources that can be utilized. The city is already evaluating new groundwater and surface water supplies. This information would be included in the SWPP regarding alternative water sources.

- ▶ Management planning is ultimately the most important element of the SWPP. The management plan identifies specific activities that will be pursued by the city of Bozeman to protect their water resources. The city will benefit by taking a proactive approach to source water protection in their watersheds. It is anticipated that most of the management effort will focus on coordination with other government agencies and periodic surveys of the watersheds. It may be necessary to conduct a few special studies to determine actual risk and consequences for selected contaminant sources. This information may be needed before decisions can be made on management activities.

Completion of the SWPP requires participation by an Advisory Committee. The Advisory Committee includes representatives with interests in the city of Bozeman watersheds and provides a public process for decision making. For the city of Bozeman, the Advisory Committee would most likely include representatives from the following:

- ▶ City of Bozeman

- ▶ Gallatin County Planning

- ▶ Gallatin County Local Water Quality District

- ▶ Gallatin National Forest Bozeman Ranger District

- ▶ Gallatin National Forest Supervisor's Office

- ▶ Private Industry (mining, timber, livestock)
- ▶ Citizen Groups (local watershed group, others)

The SWPP is formerly adopted by the city of Bozeman. It is preferable that the city pass a resolution to implement the SWPP and to set aside appropriate funding for program implementation. Program implementation is subsequently managed by city staff.

Contaminant Source Inventory Updates

It is a requirement for the state of Montana to update the contaminant source inventory on a five-year basis. Thus, the city of Bozeman has no regulatory obligation at this time pertaining to updating of the SWDAR.

However, it is preferable and advisable that the city of Bozeman take charge of these information updates. The city may require updating of both the Contaminant Source Inventory and the Susceptibility Assessment on a one to two year basis. This requirement can be developed as a management activity in the SWPP. The work can be completed by city staff, such as a water system operator.

7 REFERENCES

Chapman, D. (Ed.) (1992) *Water Quality Assessments*, Chapman & Hall, Ltd., London, UK.

Custer, S. (unpublished) GIS data for geology and hydrostratigraphy were provided in ArcView GIS format on CD-ROM, Montana State University, Department of Earth Sciences.

DEQ (1999) Source Water Protection Program, USEPA Approved, November 1999, Montana Department of Environmental Quality, Helena, MT.

DEQ (2000) DRAFT Montana 303(d) List, A Compilation of Impaired and Threatened Waterbodies in Need of Water Quality Restoration, Part A Water Quality Assessment Results (April 1) and Part B Water Body Ranking, Priority Lists, and Schedule (April 13), Montana Department of Environmental Quality, Helena, MT.

ESRI (1996) ArcView GIS v. 3.2 (2000), Environmental Systems Research Institute, Inc., Redlands, CA.

Fischer, H. B., E. J. List, R. C. Y. Koh, J. Imberger, N. H. Brooks (1979) *Mixing in Inland and Coastal Waters*, Academic Press, Inc., Orlando, FL.

Gupta, R. S. (1989) *Hydrology and Hydraulic Systems*, Prentice Hall, Englewood Cliffs, NJ.

Hackett, O. M., F. N. Visser, R. G. McMurtrey, and W. L. Steinhilber (1960) *Geology and Ground-Water Resources of the Gallatin Valley, Gallatin County, Montana, U.S. Geological Survey Water-Supply Paper 1482 (MSU I 19.13:1482 text & plates)*.

Kendy, E. and R. E. Tresch (1996) *Geographic, Geologic, and Hydrologic Summaries of Intermontane Basins of the Northern Rocky Mountains, Montana, U.S. Geological Survey Water Resources Investigations Report 96-4025, Helena, MT.*

Lageson, D. R. (1989) *Reactivation of a Proterozoic Continental Margin, Bridger Range, Southwestern Montana, Montana Geological Society 1989 Field Conference Guidebook: Montana Centennial Edition, Geological Resources of Montana, Vol. 1, p. 279 – 298 (MSU: QE1.B5 1989 V. 1).*

Maddaus, W. O. (1987) *Water Conservation*, American Water Works Association, Denver, CO.

McMannis, J. W. (1952) *Geology of the Bridger Range Area, Ph. D. Thesis, Princeton University, Princeton, NJ, (MSU: QE134.B74M3 1952, Special Collections).*

MSE-HKM Engineers, Inc. (1998) *Wastewater Facility Plan for Bozeman, Montana, Prepared by MSE-HKM Engineers, Inc., 601 Nickles Dr., Bozeman, MT.*

MSE-HKM Engineers, Inc. (1997) *Water Facility Plan for Bozeman, Montana, Prepared by MSE-HKM Engineers, Inc., 601 Nickles Dr., Bozeman, MT.*

Roberts, A. E. (1966) *Stratigraphy of Madison Group Near Livingston Montana, and Discussion of Karst and Solution-Breccia Features, U.S. Geological Survey Professional Paper 526-B (MSU: I 19.16:526-B).*

Roberts, A. E. (1972) *Cretaceous and Early Tertiary Depositional and Tectonic History of the Livingston Area, Southwestern Montana, U.S. Geological Survey Professional Paper 526-C (MSU: I 19.16:526-C).*

Skipp, B., D. R. Lageson, and W. J. McMannis (1999) *Geologic Map of the Sedan Quadrangle, Gallatin and Park Counties, Montana, U.S. Geological Survey, Geologic Investigations Series I-2634, Version 2.0.*

USDA-FS (ca. 1987) *Gallatin Forest Plan, U. S. Department of Agriculture Forest Service, P.O. Box 130, Bozeman, MT.*

USFS (2000) *Steve Swain, GIS Data, 587-6751; Lin Burton, Range Allotments, 522-2540; Jim Deavitt, GNF Plan, 587-6749; Sherm Sollid, Minerals, 587-6709; Steve*

Cassani, Timber Harvest, 522-2569; Reggie Clark, Range Allotments, 522-2520; Tim Brickell, Fire Management, 522-2546.

APPENDIX A

SWDAR CERTIFICATION CHECKLIST

APPENDIX B

WATER QUALITY DATA FOR REGULATED PARAMETERS

APPENDIX C

PLUME CALCULATION WORKSHEETS

APPENDIX D

GEOLOGICAL FORMATIONS OF GALLATIN COUNTY

APPENDIX E

BOZEMAN WATER BALANCE

APPENDIX F

GALLATIN FOREST PLAN MANAGEMENT AREA DESCRIPTIONS

APPENDIX G

GRAZING ALLOTMENT INFORMATION

APPENDIX H

TIMBER HARVEST CONTRACT

APPENDIX I

SANITARY SURVEY OF WATER SOURCES