

University of Montana

ScholarWorks at University of Montana

Graduate Student Theses, Dissertations, &
Professional Papers

Graduate School

1993

Predicting conflicts between land use and land suitability Rattlesnake Valley Missoula Montana

Candis A. Van der Poel
The University of Montana

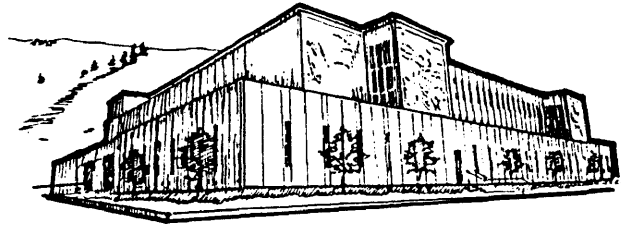
Follow this and additional works at: <https://scholarworks.umt.edu/etd>

Let us know how access to this document benefits you.

Recommended Citation

Van der Poel, Candis A., "Predicting conflicts between land use and land suitability Rattlesnake Valley Missoula Montana" (1993). *Graduate Student Theses, Dissertations, & Professional Papers*. 4749.
<https://scholarworks.umt.edu/etd/4749>

This Thesis is brought to you for free and open access by the Graduate School at ScholarWorks at University of Montana. It has been accepted for inclusion in Graduate Student Theses, Dissertations, & Professional Papers by an authorized administrator of ScholarWorks at University of Montana. For more information, please contact scholarworks@mso.umt.edu.



Maureen and Mike MANSFIELD LIBRARY

The University of
Montana

Permission is granted by the author to reproduce this material in its entirety, provided that this material is used for scholarly purposes and is properly cited in published works and reports.

*** Please check "Yes" or "No" and provide signature***

Yes, I grant permission

No, I do not grant permission

Author's Signature Candis Van der Poel

Date: 1/13/94

Any copying for commercial purposes or financial gain may be undertaken only with the author's explicit consent.

PREDICTING CONFLICTS BETWEEN LAND USE AND LAND SUITABILITY,
RATTLESNAKE VALLEY, MISSOULA, MONTANA

by

Candis A. Van der Poel

B. A.; Geology, University of Montana,

Missoula, Montana, 1979

Presented in partial fulfillment of the requirements

for the degree of

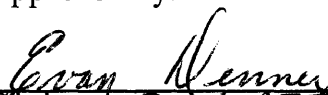
Master of Science


Rural, Town, and Regional Planning

University of Montana

1993

Approved by:


Chairman, Board of Examiners


Dean, Graduate School

1-24-94
Date

UMI Number: EP40213

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



UMI EP40213

Published by ProQuest LLC (2014). Copyright in the Dissertation held by the Author.

Microform Edition © ProQuest LLC.

All rights reserved. This work is protected against unauthorized copying under Title 17, United States Code



ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

314 1-7-94

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	iii
LIST OF ILLUSTRATIONS	iv
INTRODUCTION	1
BACKGROUND	4
Study Area	6
Land Use	6
Physical Setting	10
Topography	10
Geology	12
Soil Classification	18
SUITABILITY ANALYSIS	24
Methods	24
Data Collection	25
Map Data Entry	25
Database Development	26
Data Analysis	26
Slope	26
Drainage	29
Slope Stability	32
RESIDENTIAL BUILDOUT MODEL	37
Estimating Relative Cost	38
Estimating Allowable Density	40
Estimating Development Potential	43
PREDICTING POTENTIAL CONFLICTS	47
Discussion of Results	48
Slope	48
Drainage	50
Slope Stability	50
Interpretation	53

SUMMARY AND CONCLUSIONS	54
APPENDIX	57
SELECTED BIBLIOGRAPHY	58

ACKNOWLEDGEMENTS

Many thanks to the residents of the Rattlesnake Valley who served on the Comprehensive Plan and Zoning Committee. Their vision of balanced land use and preservation of landscape qualities was the primary motivation for this study. Thanks, also, to the planners at the Missoula Office of Community Development for providing valuable insight into the reality of small town planning, as well as cheerful encouragement. Lastly, I wish to thank Tony for introducing me to the Valley thirteen years ago and revealing its many splendors.

This paper is dedicated to the memory of my mother, Miriam R. Steward.

LIST OF ILLUSTRATIONS

Figure	Page
1. Procedural flowchart for predicting conflicts between physical attributes and development potential	3
2. Study Area, Rattlesnake Valley, Missoula, Montana	7
3. Property boundaries	9
4. Slope classification	13
5. Geology	15
6. Soil classification	19
7. Slope stability ranks	28
8. Drainage suitability ranks	31
9. Slope stability suitability ranks	36
10. Relative cost of building ranks	41
11. City and County zoning designations	42
12. Density probability ranks	44
13. Development potential ranks	46
14. Potential conflict ranks - slope and development potential	49
15. Potential conflict ranks - drainage and development potential	51
16. Potential conflict ranks - slope stability and development potential	52

CHAPTER I

INTRODUCTION

Proposed land development raises concerns about risks to public health and safety and overall costs to society. Many of these concerns could be addressed by assessing the requirements of the proposed use and the capacity of the land to satisfy those requirements. Where discrepancies exist, potential conflicts, that result in increased building costs or property damage, may occur. The ability to predict potential conflicts between land use and land suitability may help minimize public risks and liabilities. This paper presents a method for predicting potential conflicts by comparing the intensity and location of projected land use with an analysis of land suitability.

Successful planning requires an evaluation of existing conditions before recommending options for future use. For this reason, suitability analysis are often conducted prior to developing community plans (Steiner 1991). The ultimate purpose of a land suitability analysis is to reduce potential conflicts by identifying land use constraints inherent to the landscape. A suitability analysis cannot, by itself, predict conflicts. Prediction requires both a knowledge of the future land use as well as an understanding of the ability of the land to provide for that use.

A landscape may be predisposed to a particular use by virtue of a variety of factors including its history, adjacent land use, existing land use controls, and the demand for a particular use (Sedway 1988). These factors provide the elements to model the pattern and intensity of future use. Communities which have instituted land use controls, such as zoning, may have considered many of these factors before developing the zoning plan. For this reason, zoning can be an important element for predicting land use. Demand for a particular use is, in part, driven by the cost to develop that use (Sedway 1988). Development costs, therefore, are also important factors in modeling future land use.

The primary objective of this study is to predict conflicts between land suitability and future land use. A secondary objective is to evaluate the effectiveness of existing land use controls at protecting the public health and safety and minimizing overall costs to the community. The results of the study may be used to support or contest current zoning designations and provide rationale for recommended changes.

The Rattlesnake Valley, a neighborhood in Missoula, Montana, was chosen for the study area because of its diverse landscape and unique regulatory status. The Rattlesnake Valley possesses a wide range of physical attributes that ensure a complete range of suitabilities will be represented. Furthermore, the study area is currently zoned for various levels of residential development but is still mostly

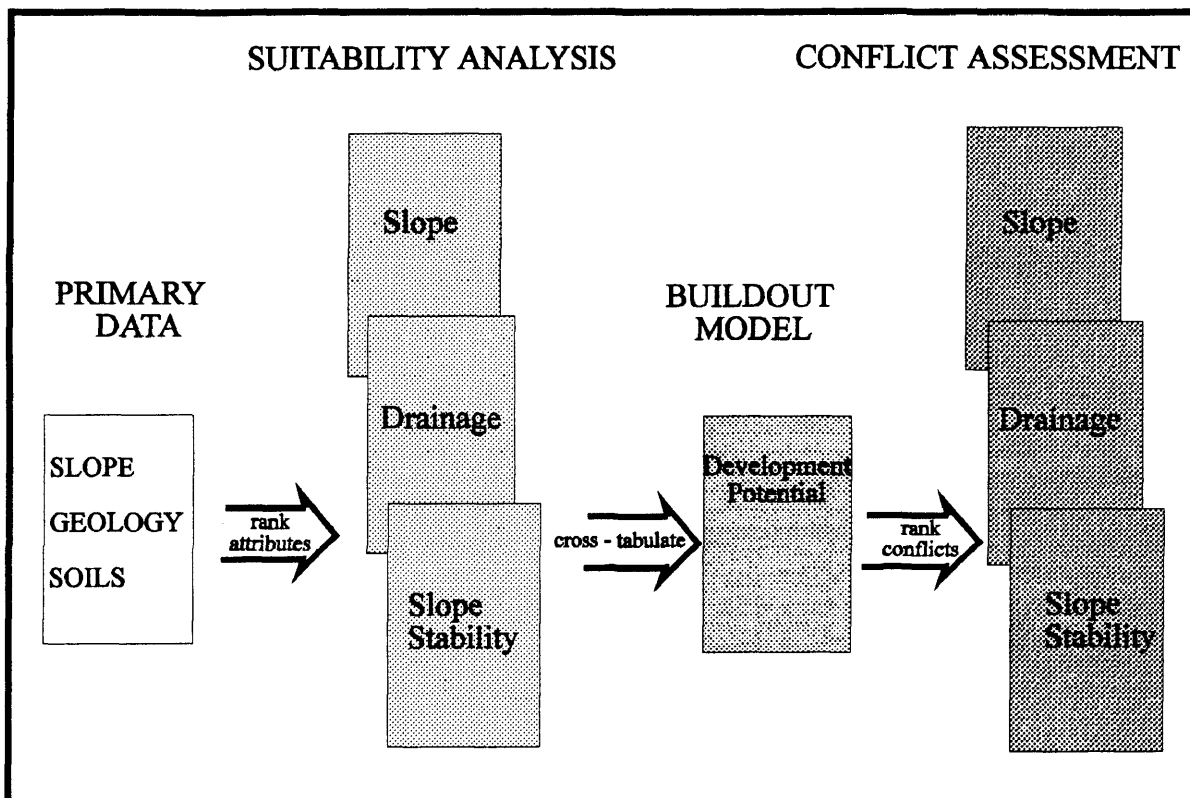


Figure 1. Procedural flowchart for predicting conflicts between physical attributes and development potential.

undeveloped. All of these conditions are necessary to assess potential conflicts.

Figure 1 illustrates a general procedure for predicting potential conflicts between different levels of residential land use and ranks of land suitability in the Rattlesnake Valley. The technique compares the suitability of the land, based on certain construction requirements, to a modeled buildout of residential development. The result is an ordinal ranking of the potential conflicts.

CHAPTER II

BACKGROUND

An amendment to the Missoula Urban Comprehensive Plan for the Rattlesnake Valley was adopted by the City and the County of Missoula in 1988 (City of Missoula 1988). The purpose of the plan was to establish community objectives and provide policy to guide neighborhood development. The plan describes the attributes and character of Rattlesnake Valley and assesses the need for public services and facilities. As a result of this assessment, thirteen goals and objectives for future development were identified. These goals and objectives call for preserving air and water quality, maintaining open space and wildlife habitat, enhancing both urban and natural forests, and improving traffic circulation and safety. Additionally, a system to monitor the continued effects of growth was requested. A residential density cap of 5500 was also proposed based on the capacity of the main sewer line serving the area.

The lower Rattlesnake Valley is within City limits and has been zoned for moderate (four to six dwelling units per acre) density, single-family dwellings since 1932. The upper and middle portions of the Valley were annexed into the City in 1989. At this time, moderate to low density (less than four dwelling units per acre), single family residential zoning was applied. This interim zoning closely

matched the zoning previously assigned to these lands while under the jurisdiction of the County. All interim zoning expired in June, 1992, leaving much of the study area unzoned.

In January, 1991, a citizen's committee was formed to develop proposals for permanent zoning for the recently annexed lands, with the assistance of the Missoula Office of Community Development (OCD). A necessary part of this task was to update the 1988 Rattlesnake Valley Comprehensive Plan Amendment to reflect the change in jurisdictional boundaries and supplement resource information (City of Missoula 1992a). The resulting zoning proposal presented to the Missoula City Council in March, 1993, was based largely on the goals outlined in the updated Amendment. This zoning proposal attempted to adhere to the land-sensitive policy stated in the updated Amendment:

...future development in the Rattlesnake is not simply a numbers game. The number of additional dwelling units to allow is only part of the equation in looking to guide future development. Future development should occur where it is most appropriate generally, and in a manner which is appropriate for the particular site conditions. Appropriate in this context means two things: that the natural environment is protected, and that the public health, safety, and welfare are protected" (City of Missoula 1992).

In June, 1993, the Missoula City Council majority rejected the zoning proposal leaving much of the Rattlesnake Valley unzoned. Without a ratified zoning plan, subdivision and building applications must be reviewed according to their compliance with the goals of the 1992 Comprehensive Plan Amendment and previous County zoning designations.

The resource data compiled for the updated 1992 Comprehensive Plan Amendment is used in this study to establish land suitability. In unzoned portions of the study area, previous County zoning designations are applied for modeling development potential.

Study Area

The study area is approximately eight square miles and includes land administered by the City and County within the lowermost Rattlesnake watershed (Figure 2). This area was chosen because of its diverse physical characteristics which present various constraints to development. The area is sparsely populated and much of it was subdivided for future building. Excluded from the study area is the medium to high density residential development located on the valley bottom and lower hillsides. This exclusion divides the study area into two subareas: East Rattlesnake and West Rattlesnake.

Land Use

The most recent large-scale subdivision of land in the Rattlesnake was in the late 1980s when Entech, Inc. (formerly Sunlight Development Corporation, a subsidiary of Montana Power Company), sold its interest in 939 acres. Most of this land is privately owned and was subdivided into parcels ranging from 1 acre to

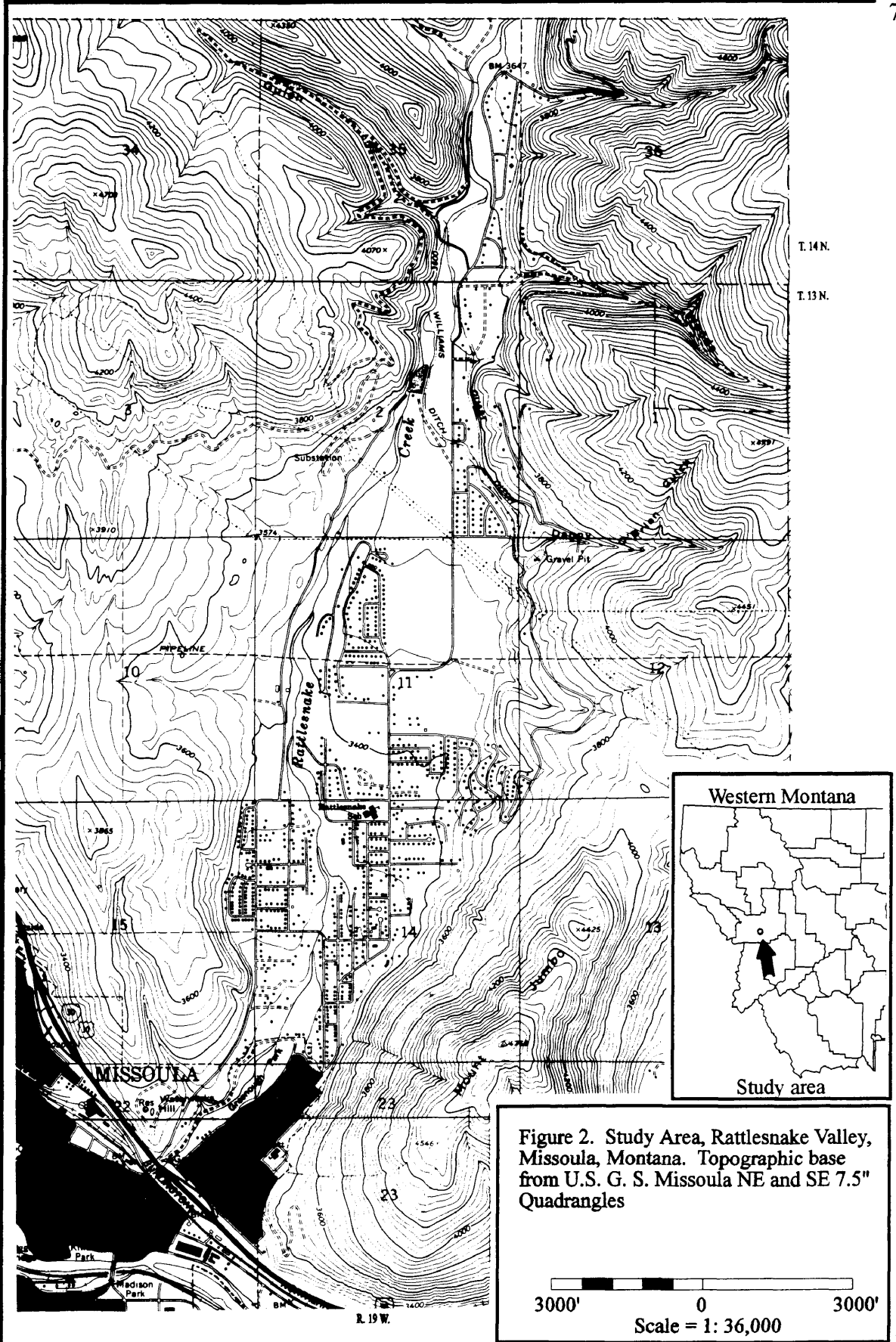


Figure 2. Study Area, Rattlesnake Valley, Missoula, Montana. Topographic base from U.S. G. S. Missoula NE and SE 7.5" Quadrangles

3000' 0 3000'
Scale = 1: 36,000

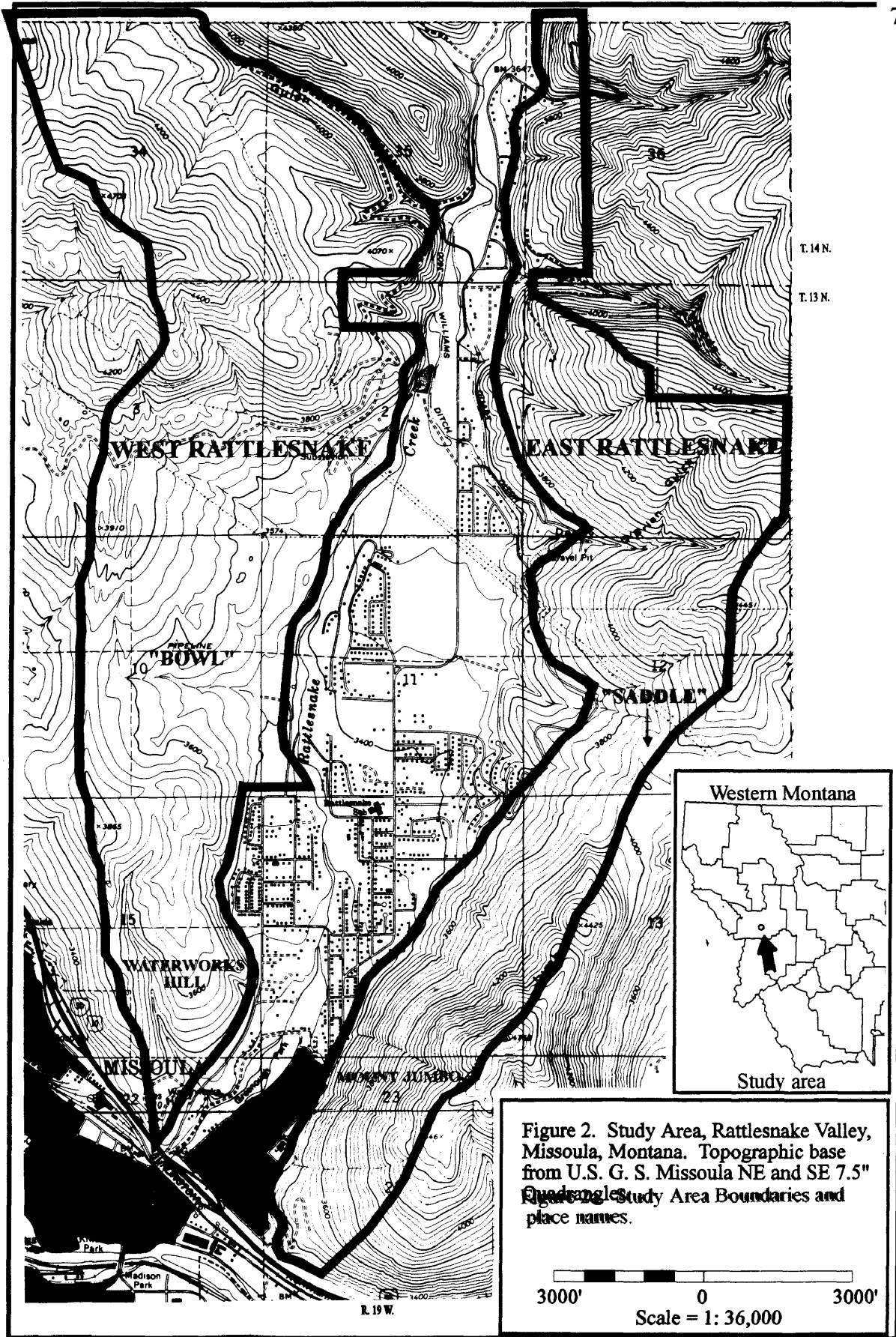


Figure 2. Study Area, Rattlesnake Valley, Missoula, Montana. Topographic base from U.S. G. S. Missoula NE and SE 7.5" Quadrangles. Study Area Boundaries and place names.

3000' 0 3000'
Scale = 1: 36,000

80 acres. As of August, 1993, only three of these parcels have new construction. Montana Power continues to own the land beneath and adjacent to the Rattlesnake Dam, the westside substation, and several utility corridors. The City of Missoula, which owns approximately 352 acres of open space park land, is the largest landowner. Property boundaries within the study area are shown in Figure 3.

The primary land use in the Rattlesnake Valley is single family housing. In addition, there are several duplexes, apartment buildings, schools, churches, group homes, and a nursing home. None of these institutions is within the study area. Most of the residential development is confined to the valley bottom, although a few subdivisions are situated on lower hillslopes. In the early twentieth century the valley was used for hunting and fishing by the local residents, and later for agricultural purposes (Poe and Poe 1992). Horse, cattle, and llama grazing is the dominant agricultural use today.

Approximately ninety percent of the study area can be classified as undeveloped open space. The development "rights" of some of the open space lands are owned by the City of Missoula or have been transferred to land trusts (City of Missoula 1992a). The majority of this open space is privately owned, and because of current zoning, may be urbanized.

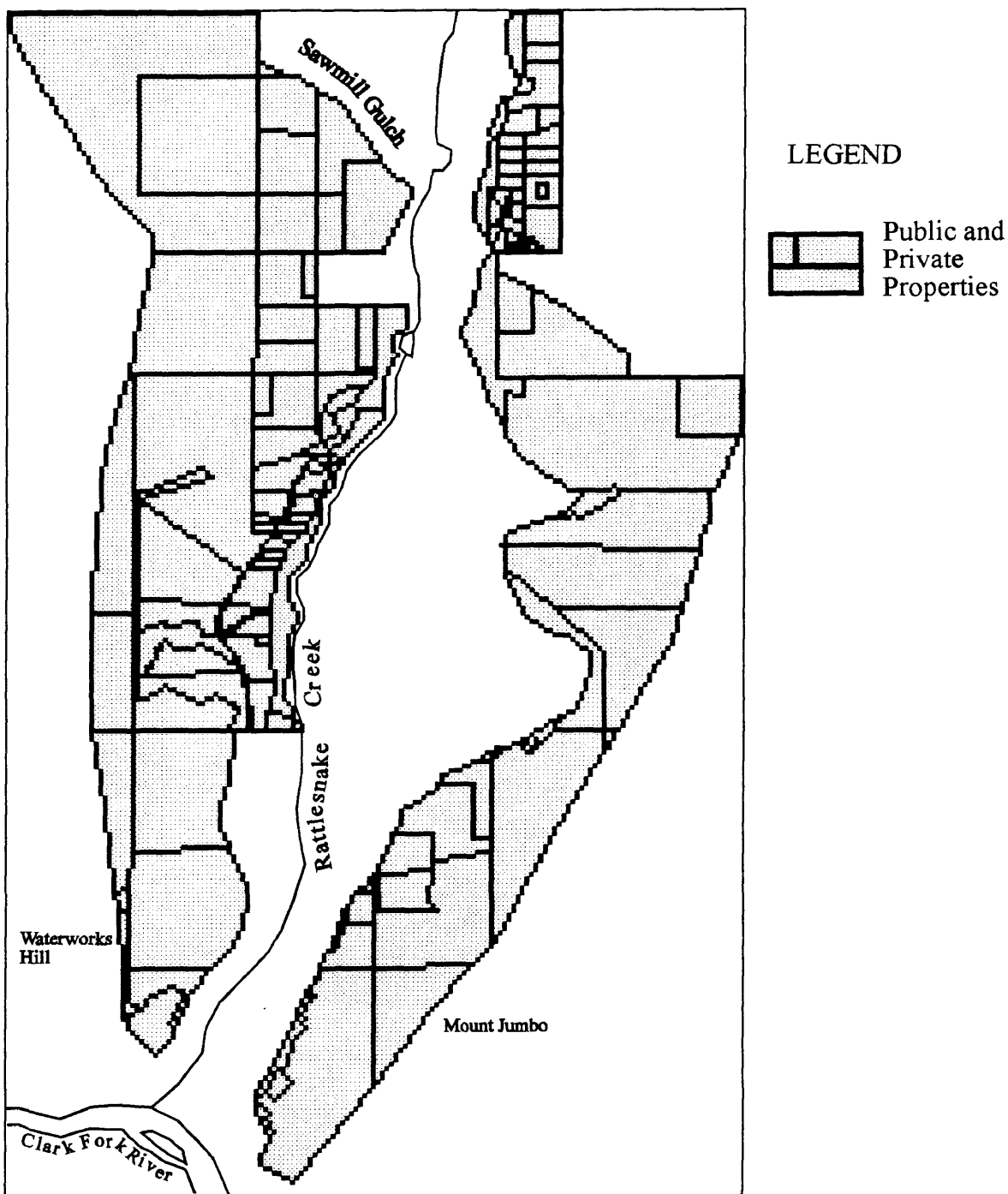
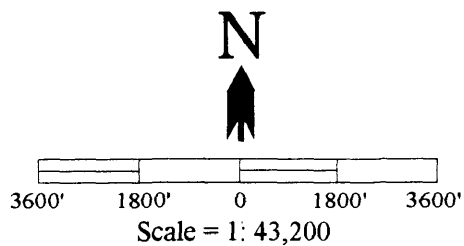


Figure 3. Public and private property boundaries, Rattlesnake Valley.



Physical Setting

The Rattlesnake Valley is located on the northeast edge of the Missoula Valley. Within the study area, the valley trends north-south and is approximately four miles long. Rattlesnake Creek flows through the middle, from north to south. Fifteen hundred feet north of the confluence of Rattlesnake Creek and the Clark Fork River the valley bottom is approximately two thousand feet wide. The adjacent hillslopes are underlain by shallow bedrock and rise steeply from glacial outwash and alluvial terraces. The valley expands to approximately one mile wide approximately one and one half miles north of the south entrance. The hillslopes at this point are gentle to moderately steep, and the material consists of unconsolidated clay-rich sediments. One mile north of the widest part, the valley narrows, and is again confined on both sides by steep bedrock.

Mid-elevation south-facing hillslopes are dominantly open grasslands. Douglas firs dominate north-facing slopes and higher elevations. Remnant native vegetation on the valley bottom consists of ponderosa pine, black cottonwood, and a wide variety of riparian shrubs, forbes, and sedges (Habeck 1984).

Topography

The south quarter of the East Rattlesnake is dominated by Mount Jumbo. The mountain is gently rounded and rises abruptly from the valley bottom at approximately 3400 feet to its highest point of 4768 feet in less than 3000 horizontal feet. Slopes are generally greater than 40 percent along the north, south, and west faces. Mount Jumbo is separated from a steep north-south

trending ridge to the north by a low, nearly flat saddle. The lowest point of the saddle is approximately 4000 feet. North of the saddle, a ridge rises steeply to an elevation of 4800 feet, the highest point in the study area. The west-facing slopes of this ridge are greater than 30 percent. Woods Gulch, Danny O'Brien Gulch, and numerous smaller east-west trending drainages dissect the East Rattlesnake.

The West Rattlesnake is characterized by more numerous hills and irregular topography. The southwest portion is divided into two, parallel, north-south trending hills, collectively referred to as Waterworks Hill. These hills are similar to Mount Jumbo because they also rise steeply from the valley bottom at slopes of 35 to 40 percent. The crests of these hills are relatively flat, and reach elevations of 3600 to 3800 feet. The two hills coalesce approximately one mile north of the south study area boundary. At this point there is an abrupt transition from a steep hillside to a gentle bowl-like feature which dominates the middle portion of the West Rattlesnake. The bowl is approximately a mile and a half wide, north to south, and one mile wide east to west. It is bounded by steep slopes on the north and south sides. East to west, the slopes rise gently and are characterized by low north-south trending ridges and broad drainages. Slopes range between 0 to 15 percent in this area. North of the bowl, the topography steepens abruptly. The northwest portion rises to a elevation of 4700 feet, and then drops rapidly to the elevation of Sawmill Gulch, about 3800 feet. The topography in this area is irregular and forms numerous, small bowl-like depressions separated by narrow ridges. Locations and names of geographic features are shown on the overlay to

Figure 2 (Figure 2a).

Elevations were obtained from the U.S. Geological Survey Missoula Northeast and Missoula Southeast 7.5 minute topographic maps. The elevation contours within the study area were digitized and the slope was calculated using IDRISI, a raster-based geographic information system. A map portraying the study area divided into three slope classes is shown in Figure 4. Class boundaries are based on engineering constraints recognized by state and local health and building codes (City of Missoula 1992b, City and County of Missoula, 1991).

Geology

Bedrock geology in the Rattlesnake Valley was mapped by the U.S. Geological Survey (Nelson and Dobell 1961) and surface geology by Van der Poel (Van der Poel 1978). Both maps are consistent in their overall interpretation of the geologic events of the Rattlesnake watershed.

Bedrock consists of Precambrian metasediments which outcrop and form talus slopes on the steep sides of Mount Jumbo and Waterworks Hill. These rocks belong to the Belt Supergroup, a regional rock unit consisting of weakly metamorphosed clastic and carbonate sediments. Regional thrust faulting and recurrent normal and strike-slip faulting displaced the Precambrian sediments during the late Cretaceous and early Tertiary periods (McMurtrey, Konizeski, and Brierkrietz 1965). During the Tertiary, sediments derived from local bedrock and volcanic ash from distant sources filled the existing valleys. These sediments overlie bedrock on portions of Mount Jumbo and Waterworks Hill and were

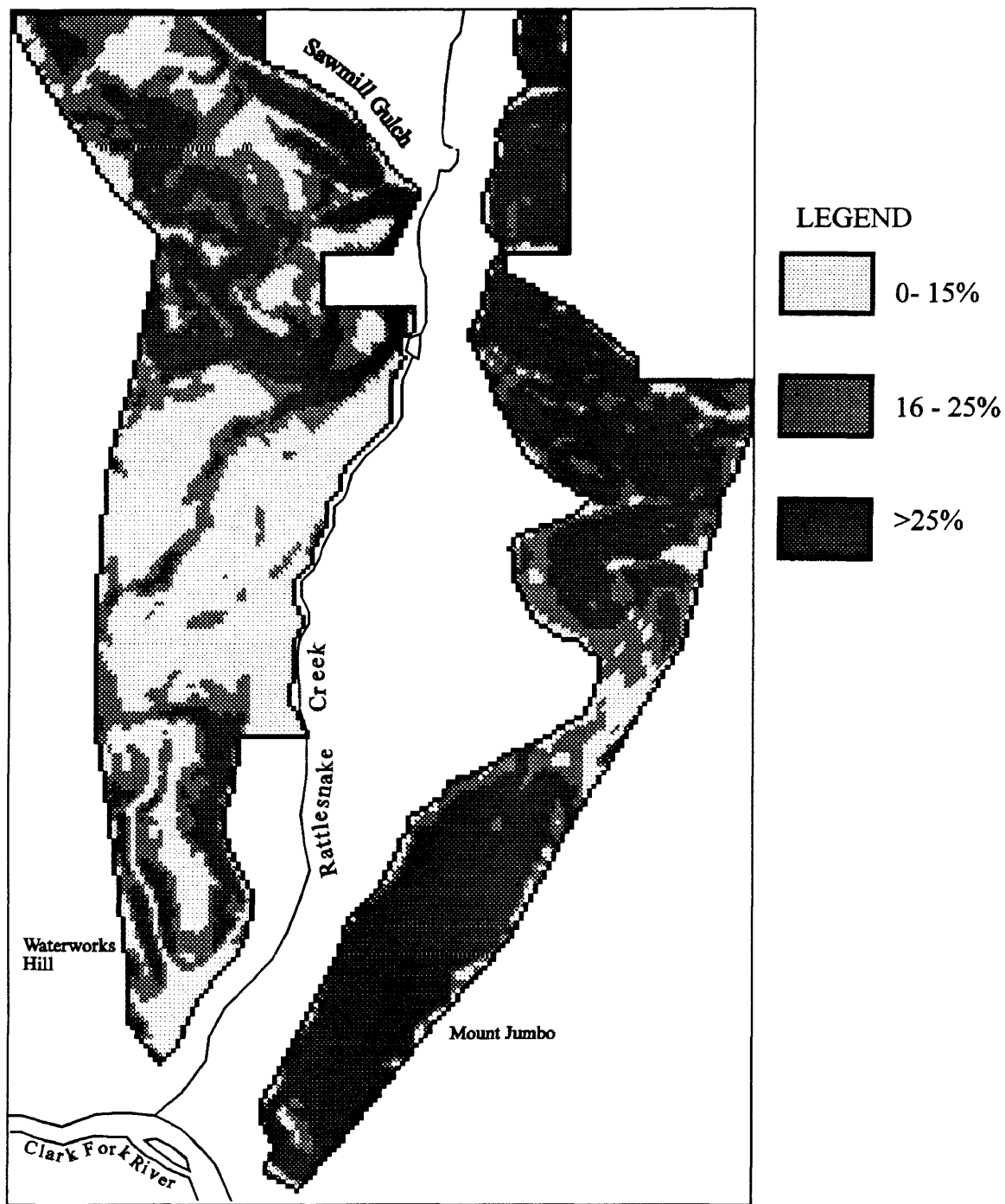
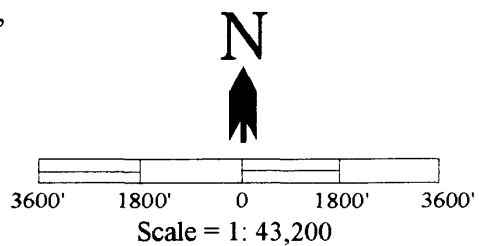


Figure 4. Slope Classification, Rattlesnake Valley.
 Source: U.S.G.S. Northeast and Southeast Missoula,
 Montana, 7.5" Quadrangles, 1978.



involved in most of the landslides found in the study area. Some landslides are interglacial and probably occurred between the recurrent filling and draining of Glacial Lakes Missoula. Horizontal benches of reworked littoral gravels, visible on the west slopes of Mount Jumbo are also vestiges of periodic Lake stands. Glacial outwash forms the uppermost terrace in the valley bottom, within which more recent alluvial terraces have been developed. The youngest alluvia consist active floodplain and fan deposits at the mouths of steep gullies.

A map of surface geology is presented in Figure 5. Geologic structural elements have been omitted because there is insufficient data to evaluate the significance of faulting and bedding plane attitude with regard to land use suitability. The map units relevant to the suitability analysis are:

- Qal - Quaternary alluvial deposits. These are composed of locally derived, well to poorly sorted, unconsolidated gravel, sand, and silt transported by recent fluvial activity. These sediments are confined to lower alluvial terraces and floodplains.

- Qc - Quaternary colluvial deposits. These accumulations of angular-to-subrounded rock fragments form moderately thick (up to 20 feet) deposits of regolith. The material is locally derived, either from Tertiary deposits or from debris accumulated at the base of Belt outcrops. These deposits are found primarily on hilltops and slopes.

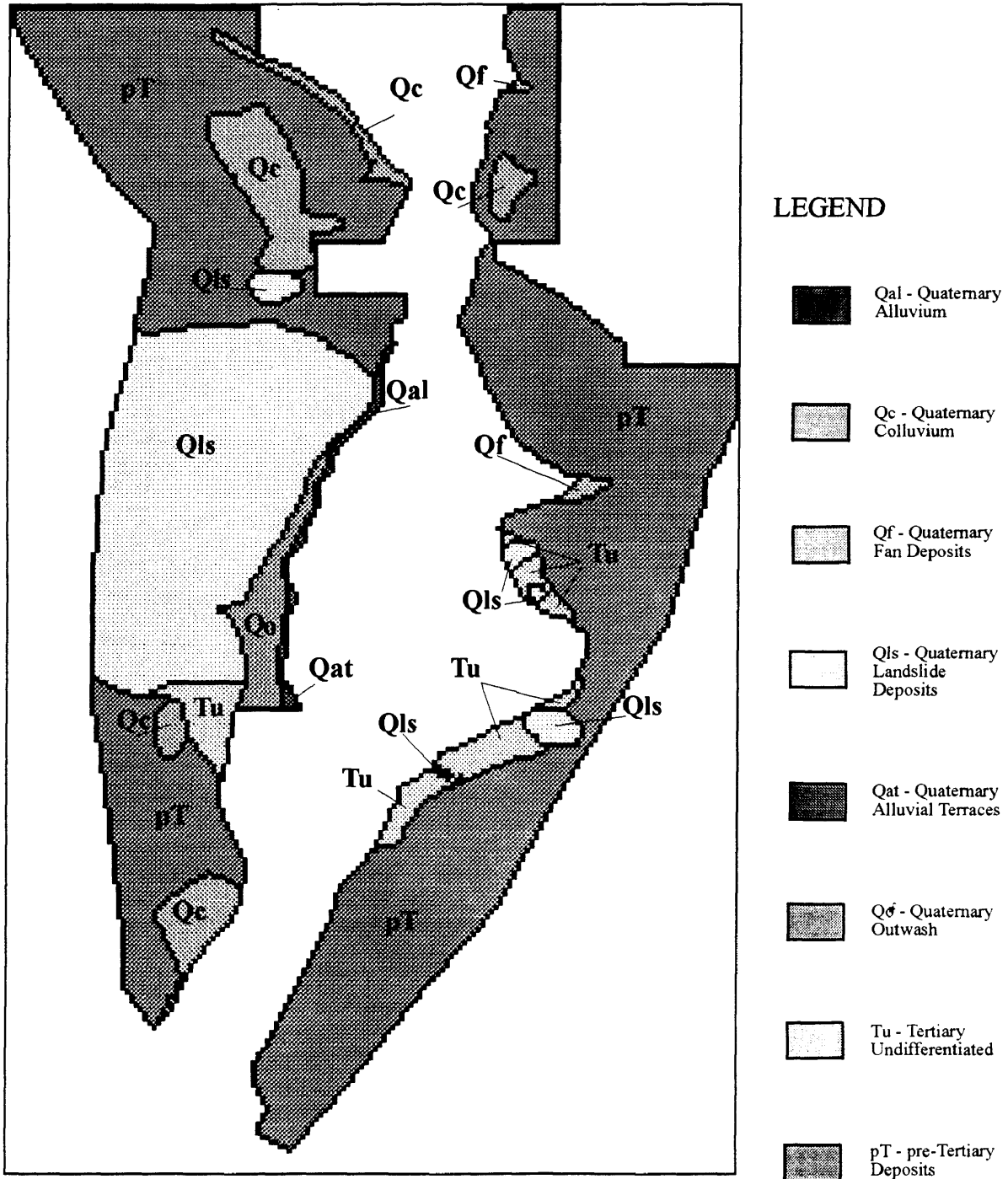
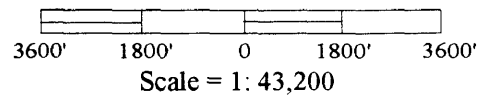


Figure 5. Geology, Rattlesnake Valley. See text for description of units. Sources: Nelson and Dobell, 1961, Van der Poel, 1978.



- Qf - Quaternary alluvial fan deposits. Fan deposits consist of unconsolidated silt, sand, gravel, cobbles, and boulders and occur at the mouths of gullies and high gradient streams. The material is locally derived from Tertiary or pre-Tertiary sediments. Alluvial fans are generally conical in cross-section and map view and typically overlie or interfinger with the uppermost glacial outwash terraces.
- Qls - Quaternary landslide deposits. Landslides are composed of highly variable material derived from Tertiary sediments. Most of these features developed during interglacial periods (15,000 - 2,000 years ago) and were probably facilitated by saturation of the clay-rich fraction within the failed mass. The most significant paleoslide underlies the entire middle portion of the West Rattlesnake. The main scarp parallels the west watershed boundary and numerous north-trending transverse ridges and swales can be identified throughout the slide. Numerous smaller slumps and earthflows have been mapped within the Tertiary sediments and some within older slides.
- Qat - Quaternary alluvial terrace deposits. Unconsolidated deposits of gravel, sand, and silt comprise these paleoalluvial deposits. The terraces form narrow and discontinuous benches approximately 10 to 50 feet above the active stream channel.

- Qo - Quaternary outwash deposits. Poorly-to-well sorted cobbles, gravel, and silt cover the uppermost alluvial surface of the valley bottom. These deposits were laid down by glacial meltwater and typically retain braided channel features on their surfaces.
- Tu - Tertiary deposits, undifferentiated. These basin fill deposits consist of sandstone, siltstone, shale, conglomerate, with some intercalated coal and ash beds. Compositionally, these deposits are highly variable both laterally and horizontally, and often are contorted by landslides and faulting. The shales typically contain expandable, montmorillonite clays derived from volcanic ash. Tertiary deposits cover some of the mid-elevation hillsides such as the saddle of Mount Jumbo and portions of Waterworks Hill.
- Pt - pre-Tertiary deposits, undifferentiated. Precambrian metasediments comprise the bedrock formations in the Rattlesnake watershed. These formations are part of the Belt Supergroup and are composed primarily of red and green argillites, grey to tan calcareous siltstone, and pink to tan quartzites. These rocks outcrop on Mount Jumbo and the ridge north, on Waterworks Hill and at higher elevations in the northwest portion of the study area. Also included in this mapping unit are narrow dikes of mafic intrusive found near the top of Mount Jumbo.

Soil Classification

Soil series for the study area were mapped by the U.S. Soil Conservation Service (1983). The series were subclassified into twenty-one map units according to the average percent slope or slope aspect.

Map units are classified into three types. Monotaxic units, or units with one major soil series, are characterized by at least 85 percent coverage of soil with similar profile characteristics (Dutton 1981). These units include the Bigarm, Bignell, Grantsdale, Moiese, Repp, Totelake, and Winkler series. The Mitten-Tevis and the Bigarm-Rock associations, which are found on the steeper slopes of the study area, are classified as complexes. A complex contains two or three major soil series in which individual series have similar properties but occur at a scale too small to map accurately. The Argiborolls-Haploborolls complex is considered a special mapping unit because the two soil series are very dissimilar, yet are sufficiently intermixed within a small area that mapping individual units is difficult. A map of soil classes is shown in Figure 6, and the following descriptions correspond to the general map units.

Argiborolls-Haploborolls complex. This unit is about 50 percent Argiborolls and 40 percent Haploborolls. Argiborolls developed from Tertiary sediments, and the texture varies considerably. These soils occur on gently-sloping

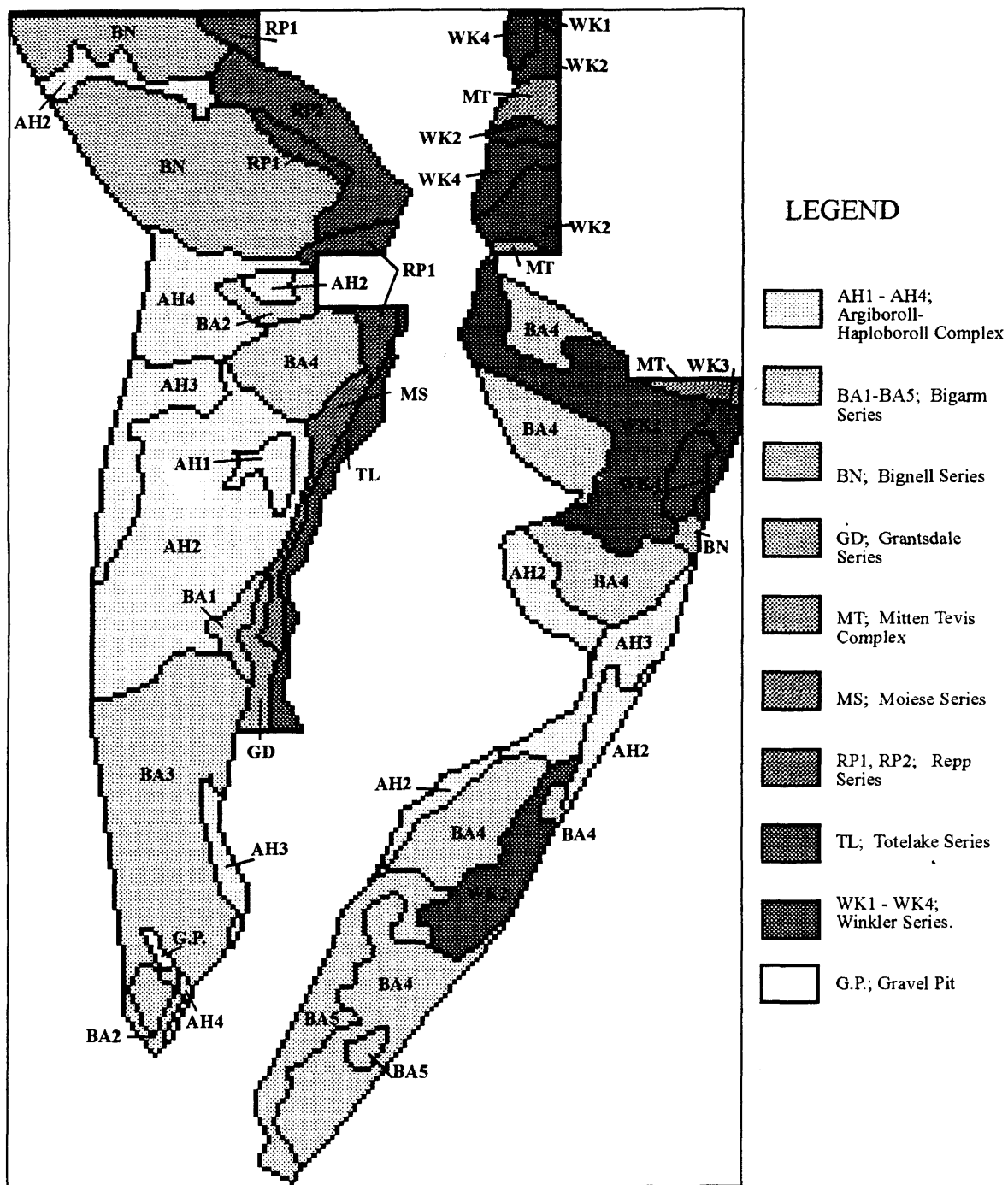
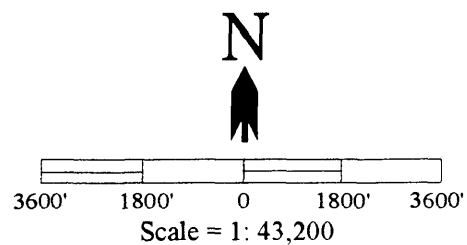


Figure 6. Soil Classification, Rattlesnake Valley. See text for description of units. Source; U.S. Soil Conservation Service, 1983.



foothills. The surface layer is typically gravelly loam to very gravelly silt loam. The subsoil may be extremely gravelly clay loam to entirely clay. The clay exhibits high shrink-swell potential. Permeability is very low to moderate and runoff is slow. Runoff rates increase with increasing slopes.

Haploborolls are generally more coarsely textured, although compositionally extremely variable. The surface layer is composed of gravelly loam to very gravelly silt loam. Subsurface material is typically gravelly loamy sand to extremely gravelly loam. Permeability of these soils is moderate to very high and runoff is slow. Runoff rates increase as slope increases.

Bigarm gravelly loam. This soil derives from alluvium and colluvium, and is very coarsely textured. This unit occurs on the lower elevation foothills in the study area. The surface layer is typically a gravelly loam about 15 inches thick. The subsoil is gravelly sandy loam to extremely gravelly loamy sand. Permeability of these soils is high because they are very porous. Runoff rate is generally slow although it increases rapidly as slope increases.

Bigarm-Rock outcrop complex. This soil is found on the steep west slopes of Mount Jumbo. The map unit is approximately 70 percent Bigarm gravelly loam and 15 percent Rock outcrop. The soil develops from colluvium composed of Precambrian argillite and quartzite. The Rock outcrops are argillite and quartzite. Permeability is moderately high and runoff rate is rapid.

Bignell gravelly loam. This soil, found in the northwest quarter of the study area, derives from a mixture of Tertiary sediments and glacial till. Surface material is generally decomposed forest litter underlain by gravelly loam. The subsoil is very gravelly clay. The soil has been mapped on slopes greater than eight percent. Permeability is moderate and runoff rate is medium.

Grantsdale loam. A very small portion of the central West Rattlesnake is covered by this soil, which is developed from alluvium. The upper surface is loam grading into extremely gravelly loamy sand at depth. Permeability is high and runoff rate is slow.

Mitten-Tevis complex. This map unit occurs in the northeast portion of the study area, generally along steep drainage slopes. Forty-five percent of the unit is Mitten gravelly silt loam and 34 percent is Tevis gravelly loam. The Mitten series forms in colluvium derived from Precambrian argillite and quartzite. The surface horizon has a high component of volcanic ash. Subsurface material ranges from very gravelly sandy loam to extremely gravelly sandy loam. Permeability is moderately high and runoff rate is rapid due to the steepness of slope.

The Tevis series also derives from clastic bedrock. Surface material is gravelly loam, and subsurface material grades from very gravelly sandy loam to extremely gravelly sandy loam. Permeability of this soil is also moderately high and runoff rate is rapid.

Moiese gravelly loam. This alluvial soil is found on alluvial fans above the active Rattlesnake Creek floodplain. The surface material is very gravelly sand loam which grades to extremely gravelly loamy sand and extremely gravelly sand at depth. Permeability is very high and runoff rate is slow.

Repp very gravelly loam and Repp very gravelly loam, cool. These two map units are distinguished primarily by slope aspect. The cool variant occurs on the north-facing slopes of the Sawmill Gulch drainage in the northeast portion of the study area. The south-facing slopes of the drainage are underlain by warmer, drier soils. These soils develop over limestone and calcareous argillite bedrock. They grade from primarily very gravelly loam at the surface to extremely gravelly loam at depth. Both units exhibit similar hydrologic properties; permeability is moderate and runoff rate is rapid.

Totelake gravelly loam. This soil, derived from alluvium and glacial outwash, is situated on the first terrace above the active floodplain. It has a very coarse texture which grades from gravelly loam at the surface to extremely gravelly loamy sand at depth. Permeability is moderately high to high and runoff rate is slow due to slope.

Winkler very gravelly sandy loam, gravelly sandy loam and gravelly loam, cool.

These map units are variants of a coarsely textured soil derived from Precambrian argillite and quartzite. Typically, they are found on steep forested slopes. The surface horizons are primarily gravelly sandy loam grading to extremely gravelly sandy loam at depth. Permeability in all these

soils is high and runoff rates are rapid.

A gravel pit was mapped in the lower southwest portion of the study area.

This unit, designated G.P., was omitted from the suitability analysis.

CHAPTER III

SUITABILITY ANALYSIS

Suitability analysis is the process by which the intrinsic character of the land is evaluated with regard to providing for a specific use (Steiner 1991). In the case of this study, the use is residential housing, which requires certain conditions for construction, specifically, level building sites, adequate drainage, and stable foundation conditions. The selection of physical criteria to evaluate suitability is based on the degree to which they influence construction conditions. The three physical attributes analyzed for suitability are slope, drainage, and slope stability.

Suitability ranks provide a rough estimate of anticipated development costs and health and safety risks (Steiner 1991). In general, the less suitable the site, the greater the expense required to adapt to its physical limitations. Steep slopes, for example, require extensive cutting and filling or elaborate engineering design. Unstable foundation conditions may cause structural problems resulting in high maintenance and repair costs.

Methods

The method used to assess suitability follows procedures described by McHarg (1969), the U.S. Geological Survey (Laird and others 1979), and the U.S. Soil Conservation Service (1975). These techniques share the same initial procedures

which were summarized by Hopkins (1977):

1. Identify land use;
2. Establish relationship of land use to physical attributes;
3. Map physical attributes;
4. Rank physical attributes related to land use requirements;
5. Combine ranked physical attributes according to established criteria for suitability; and
6. Rank the results of the combination to express a range of suitabilities.

Data Collection

Map Data Entry

Soil, geology, and elevation data were initially digitized using ROOTS, a digitizing program developed by the Laboratory for Computer Graphics and Spatial Analysis, Harvard University Graduate School of Design (ROOTS, Rel. 1). These data were originally compiled on paper base maps for the Rattlesnake Valley Comprehensive Plan Amendment Update (City of Missoula 1992a). All maps were registered to a 16,200 by 26,600 foot cartesian grid for digitizing. Grid coordinates were later converted to grid cell positions during the rasterizing process.

The digitized vector images were exported to IDRISI, a raster-based geographic information system developed by Clark University, Graduate School of Geography (IDRISI, Ver. 4.0). Vectors were converted to raster images, a process by which numeric values representing a vector feature are assigned to a grid cell. Each grid cell measures 100 feet by 100 feet or 10,000 square feet, an area which may reasonably be occupied by a single house and surrounding living

space.

Slope data were developed by first transforming the vector elevation contours into a digital elevation model (DEM) using the interpolation algorithm in IDRISI. The DEM was then used to calculate slope. Slope data are presented as percentages and are subdivided into three classes.

Database Development

Databases for both the soil and geology attributes were compiled in Quattro Pro, a commercial spreadsheet program (Quattro Pro, Ver. 4.0). Database files were exported as dBase files (dBase IV, Ver. 2.0), a format compatible with IDRISI. These database files are linked to map features by a unique identifier code.

The soil database contains twenty-one records which are classified and ranked according to permeability rate, runoff rate, and presence of expandable clay. The eight geologic map units were subdivided and ranked based on landslide criteria.

Data Analysis

Slope

Slope is a key factor in determining suitability for residential development. With other factors held constant, the greater the slope, the more site preparation is required (Uniform Building Code 1988). Building on steeper slopes also poses a greater health and safety problem than developing more gentle slopes because of the potential for effluent seepage (Dutton 1981). The Missoula City and

County Health Code restricts housing development on slopes greater than 25 percent by prohibiting on-site septic systems (Missoula City and County 1991). Slopes 16 percent to 25 percent are recognized as problematic because of special engineering designs required for stabilization. Slopes less than 15 percent are generally considered acceptable for residential development without restrictions (Uniform Building Code 1988).

Slope classes were determined based on local building and health code criteria. Relative suitability ranks were assigned to each class. These ranks consider the constraints imposed on development because of slope. The highest suitability rank is applied to areas with the lowest slopes. The ranks were then converted to numeric values in order to manipulate them mathematically. The resulting values provide an ordinal classification of the appropriateness of the land for residential development. Table 1 lists the relationship between slope class, suitability rank and associated numeric value.

Table 1.-- Suitability ranking for slope.

SLOPE CLASS	SUITABILITY RANK	NUMERIC VALUE
>25%	Poor	1
16 - 25%	Marginal	2
0 - 15%	Good	3

Figure 7 portrays suitability ranks for the study area based on slope.

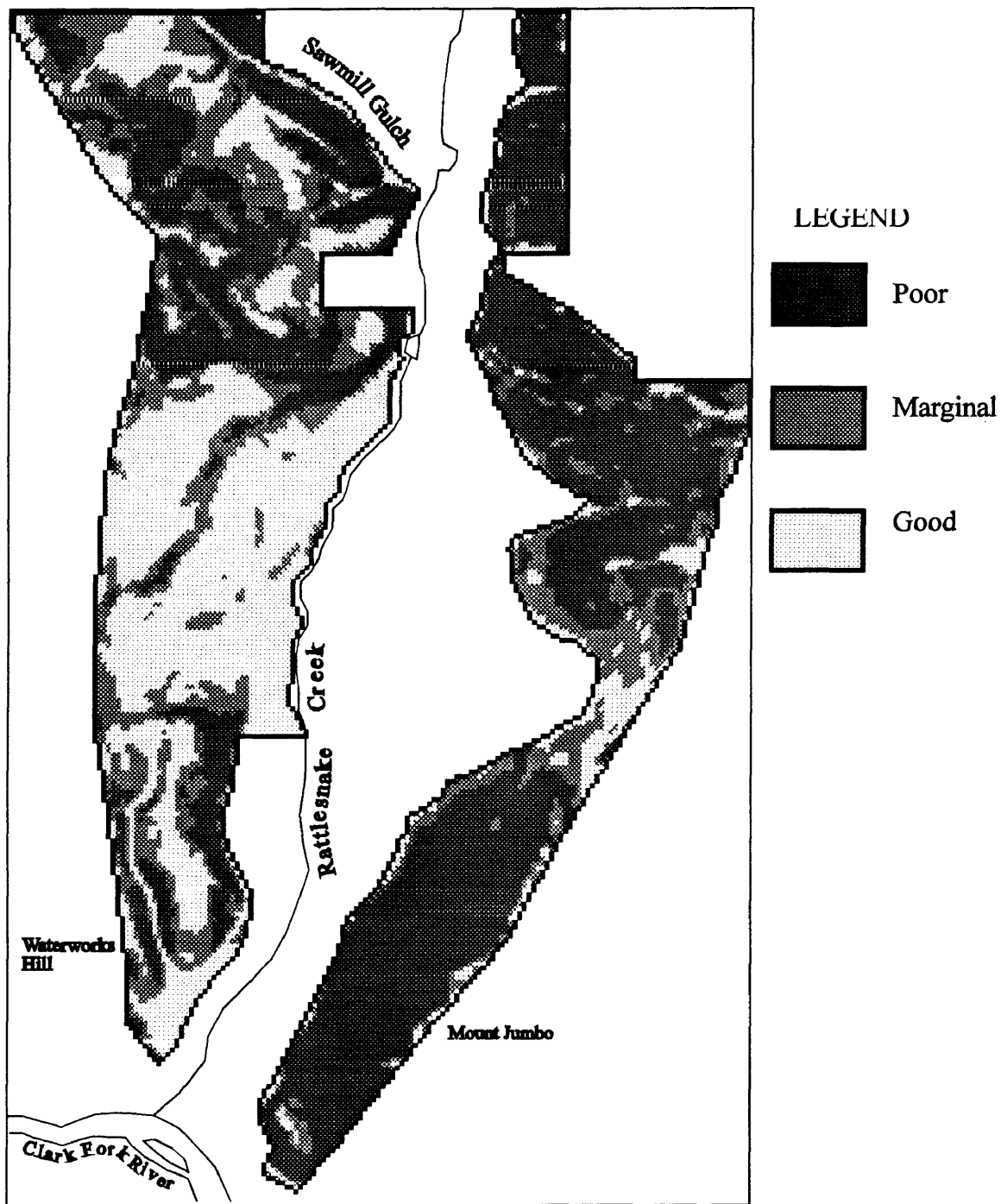


Figure 7. Slope suitability ranks, Rattlesnake Valley.

Drainage

Drainage refers to the removal of surface and shallow subsurface water from a building site. Ideal on-site conditions would permit rapid percolation of subsurface water and removal of surface water through rapid runoff. The significant factors involved in assessing drainage conditions are soil permeability rates, runoff rates, and depth to groundwater (Dunne and Leopold 1978). Permeability and runoff rates are a function of soil structure, depth, texture, slope, and aspect. Depth to the water table was not factored into the analysis because soil profiles in the study area are rarely saturated.

The drainage attributes of each soil map unit were ranked by the SCS (1983) in relative descriptive terms such as "slow", "moderate", and "rapid". Each map unit was thus assigned a single descriptor for runoff and permeability rates. The Argiborolls-Haploborolls complex, however, presented a problem for interpretation because it exhibits properties at both ends of the ranking scale. In this case, only the lowest ranks, or the least favorable ranks, were considered for suitability analysis. This conservative approach ensures that suitability is based on the worst case scenario given the available data.

The ranks were converted to numeric equivalents for purposes of combining the attribute values. A value of one is considered least favorable and three is considered most favorable. Table 2 lists the ranking for permeability and runoff rates for each map unit and the corresponding numeric values.

Table 2 -- Soil map units ranked for permeability and runoff rates.

Soil Map Unit	Permeability	Numeric Value	Runoff	Numeric Value
Argiboroll-Haploboroll Complex 0-4%	slow to fast	1	slow	1
Argiboroll-Haploboroll Complex 4-15%	slow to fast	1	slow	1
Argiboroll-Haploboroll Complex 15-30%	slow to fast	1	slow	1
Argiboroll-Haploboroll Complex 30-60%	slow to fast	1	slow	1
Bigarm gravelly loam, 0-4%	moderate	2	slow	1
Bigarm gravelly loam, 4-15%	moderate	2	medium	2
Bigarm gravelly loam, 15-30%	moderate	2	medium	2
Bigarm gravelly loam, 30-60%	moderate	2	rapid	3
Bigarm Rock outcrop Complex, 30-60%	moderate	2	rapid	3
Bignell gravelly loam, 8-30%	slow	1	medium	2
Grantsdale loam, 0-2%	fast	3	slow	1
Mitten-Tervis Complex, 30-60%	fast	3	rapid	3
Moiese gravelly loam, 0-2%	fast	3	slow	1
Repp very gravelly loam, 30-60%	moderate	2	rapid	3
Repp very gravelly loam, cool, 30-60%	moderate	2	rapid	3
Totelake gravelly loam, 2-8%	fast	3	slow	1
Winkler very gravelly sandy loam, 8-30%	fast	3	medium	2
Winkler very gravelly sandy loam, 30-60%	fast	3	rapid	3
Winkler very gravelly sandy loam, cool, 8-30%	fast	3	medium	2
Winkler very gravelly sandy loam, cool, 30-60%	fast	3	rapid	3

Suitability ranks for drainage were calculated by summing the rank values for permeability and runoff rates. The resulting values ranged from two to six. The range was divided into three suitability ranks. Each rank was reassigned a final numeric value. The relationship of summed values, suitability ranks and final numeric values is shown in Table 3.

Table 3 -- Suitability rankings for drainage.

PERMEABILITY + RUNOFF	SUITABILITY RANK	NUMERIC VALUE
2-3	Poor	1
4	Marginal	2
5-6	Good	3

The suitability ranks for drainage are portrayed in Figure 8.

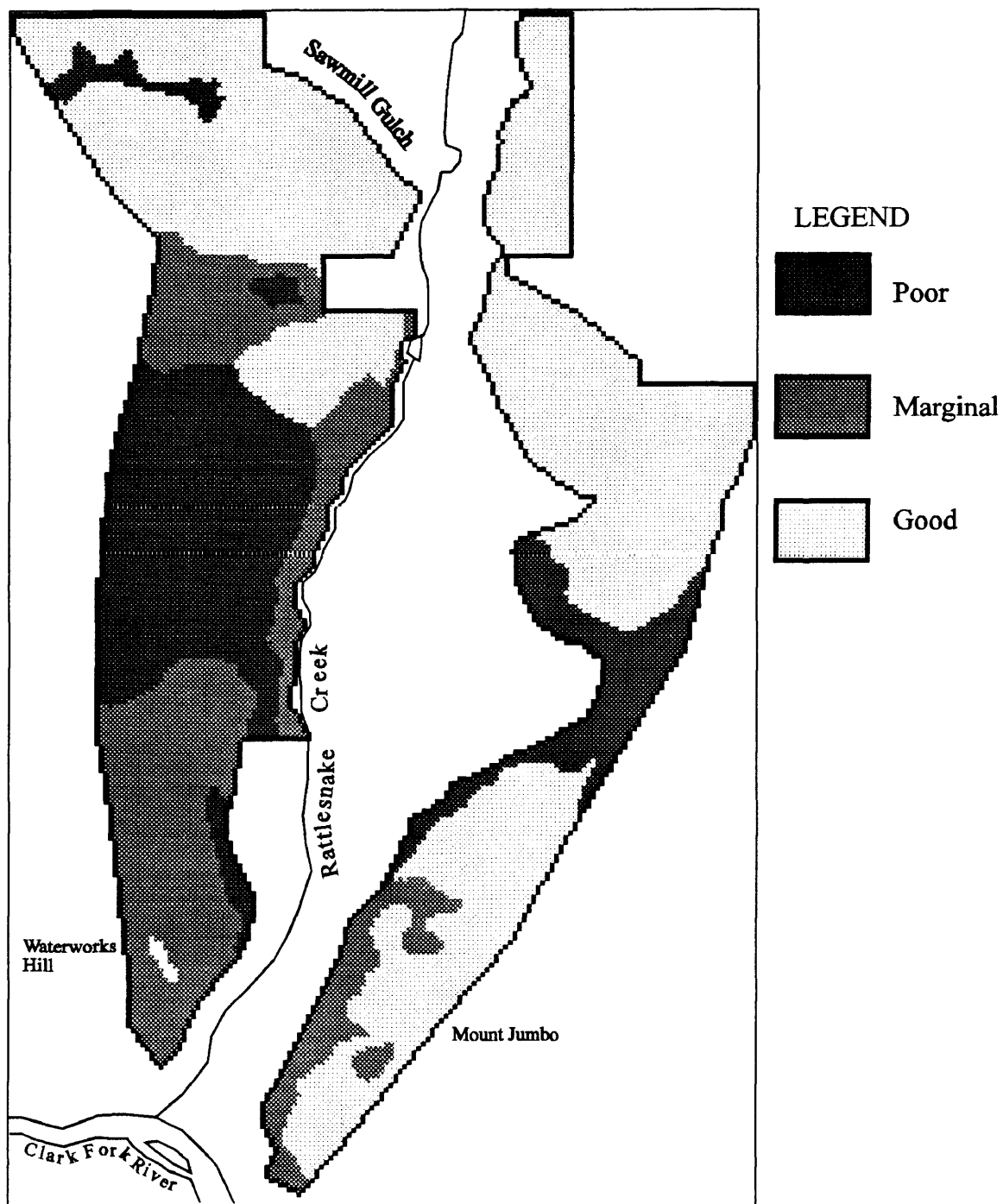


Figure 8. Drainage suitability ranks, Rattlesnake Valley.

Slope Stability

Slope failure refers to the instantaneous downslope movement of earth material that is driven primarily by gravity (Brooks and others 1991). Slope stability implies a resistance to earth movement. The U.S. Geological Survey (USGS) has identified four major factors responsible for common types of slope failures such as landslides, earth flows, slumping and rock falls. The factors are (1) the nature of the underlying bedrock or unconsolidated deposit, (2) the angle of slope, (3) rainfall, and (4) the presence of older landslide deposits (Nilson and others 1979). Each of these factors, except for rainfall, were evaluated in the study area to determine slope stability suitability. The amount of rainfall was treated as constant throughout the study area and was not factored in the ranking scheme.

Geologic attributes were ranked, on a nominal scale, for the presence of older landslides. Landslide deposits were mapped by the USGS (Nelson and Dobell 1961) and Van der Poel (1978) within the study area. A numeric value of one was assigned to landslide deposits and zero for non-landslide deposits.

The nature of the underlying material was determined from both geologic and soil attributes. Geologic units known to be susceptible to slope failure, yet still stable, were given a value of one, and the remaining deposits were assigned a value of zero. Susceptibility was based on whether landslides were documented in the same geologic units outside the study area. Landslide susceptibility of local geologic units are referenced in McMurtrey and others (1965), Nelson and Dobell

(1961), Van der Poel (1978), and Weber (1978).

Soil map units were given a value of one if expandable clays were identified as a significant attribute of that unit by the Soil Conservation Service. Expandable clays contribute to slope failure potential because of their ability to retain water. Water adds weight, decreases friction, and raises the internal pore pressure (Nilson and others 1979). This combination of factors greatly reduces the ability of the material to resist gravitational stress. Tables 4 and 5 list the rank values for geology and soil attributes.

Table 4 -- Geologic map units ranked for landslide attributes.

Geologic Map Unit	Landslides Present	Numeric Value	Landslide Susceptibility	Numeric Value
Quaternary alluvial deposits	no	0	no	0
Quaternary fan deposits	no	0	no	0
Quaternary colluvium deposits	no	0	no	0
Quaternary alluvial terraces	no	0	no	0
Quaternary outwash deposits	no	0	no	0
Quaternary landslide	yes	1	yes	1
Tertiary undifferentiated	yes	1	yes	1
Pre-Tertiary deposits.	no	0	no	0

Table 5 -- Soil map units ranked for presence of expandable clays.

Soil Map Unit	Expandable Clays Present	Numeric Value
Argiboroll-Haploboroll Complex 0-4%	yes	1
Argiboroll-Haploboroll Complex 4-15%	yes	1
Argiboroll-Haploboroll Complex 15-30	yes	1
Argiboroll-Haploboroll Complex 30-60%	yes	1
Bigarm gravelly loam, 0-4%	no	0
Bigarm gravelly loam, 4-15%	no	0
Bigarm gravelly loam, 15-30%	no	0
Bigarm gravelly loam, 30-60%	no	0
Bigarm Rock outcrop Complex, 30-60%	no	0
Bignell gravelly loam, 8-30%	yes	1
Mitten-Tevis Complex, 30-60%	yes	1

Table 5 -- Continued

Soil Map Unit	Expandable Clays Present	Numeric Value
Grantsdale loam, 0-2%	no	0
Moiese gravelly loam, 0-2%	no	0
Repp very gravelly loam, 30-60%	no	0
Repp very gravelly loam, cool, 30-60%	no	0
Totelake gravelly loam, 2-8%	no	0
Winkler very gravelly sandy loam, 8-30%	no	0
Winkler very gravelly sandy loam, 30-60%	no	0
Winkler very gravelly sandy loam, cool, 8-30%	no	0
Winkler very gravelly sandy loam, cool, 30-60%	no	0

Ranks for landslide susceptibility, landslide occurrence, and the presence of expandable clays were summed for each map grid cell. The sum of these attributes were then weighted according to the slope class in which they occur. Weighting was accomplished by multiplying the sum of the rank values by the numeric value of the slope class in the corresponding grid cell. The relationship between slope angle and slope stability is a function of the sine of the slope angle (Carson and Kirkby 1972). As slope increases, the ability of material to resist gravity decreases. The intent of this weighting scheme is to reflect this relationship between slope angle and slope stability. The resulting values ranged between zero and twelve. The range of values were reclassified to reflect three suitability ranks for slope stability. The suitability ranks were finally assigned a corresponding numeric value. Table 6 lists the range of combined attribute values, the corresponding suitability rank and the final numeric value.

Table 6 -- Suitability ranking for slope stability.

ATTRIBUTE COMBINATION VALUES	SUITABILITY RANKS	NUMERIC VALUES
2-3	Poor	1
4	Marginal	2
5-6	Good	3

Figure 9 presents the suitability map for the study area with regard to slope stability.

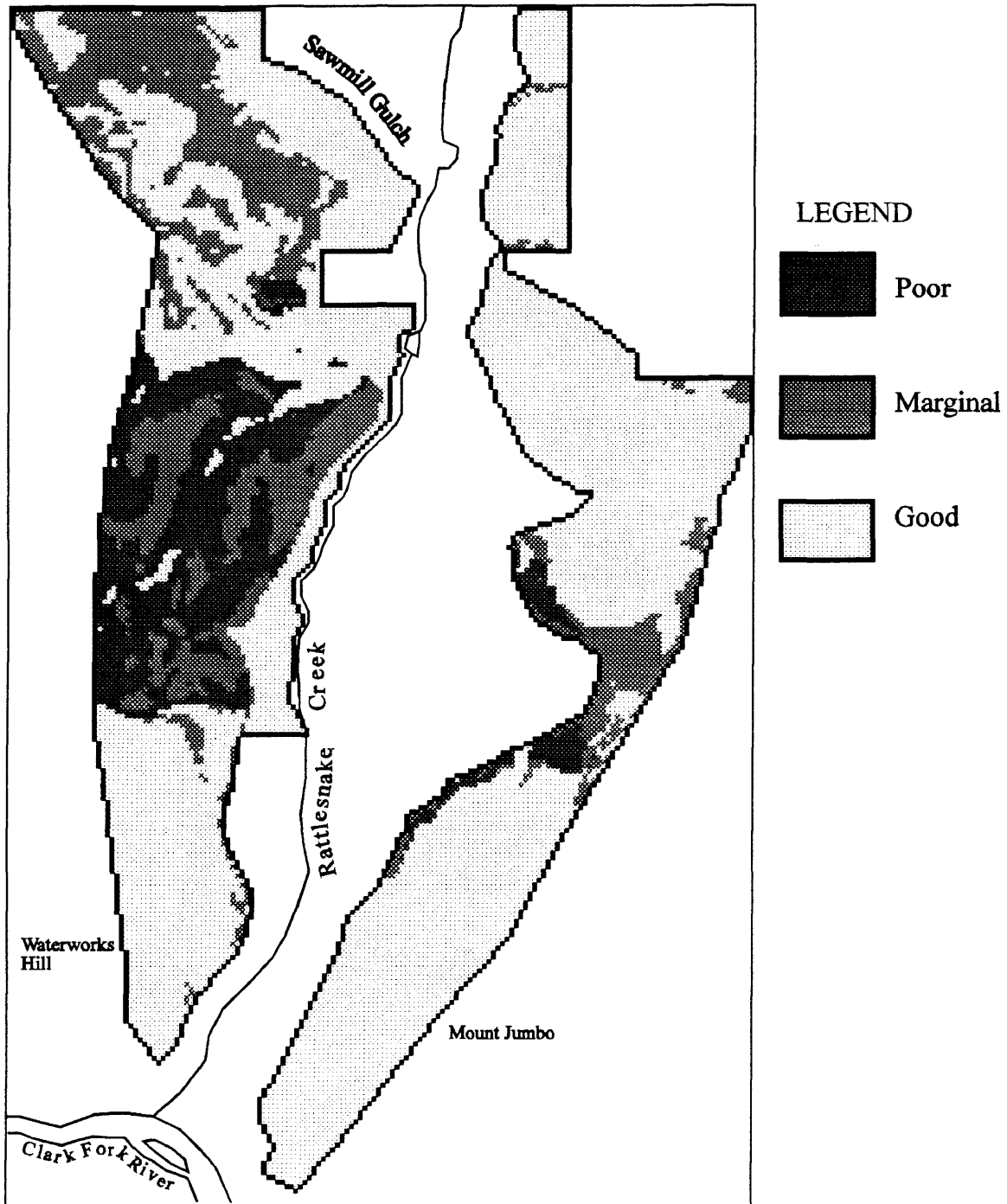
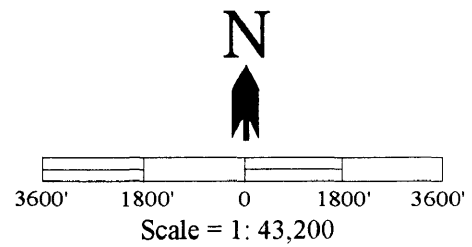


Figure 9. Slope stability suitability ranks, Rattlesnake Valley.



CHAPTER IV

RESIDENTIAL BUILDOUT MODEL

Models are decision-making tools for land use planning (Kilbridge, O'Block, and Teplitz 1970). Land use models typically attempt to predict future use based on some prevailing theory. A theory simplifies reality by using a few dominant factors to predict outcome (Hammond and McCullagh 1989). The pattern and density of residential growth may be predicted by analyzing key factors that favor expansion, or buildout, from established urban centers. The buildout model described in this study assumes that residential development in the Rattlesnake Valley depends on two primary variables, the cost of building and allowable density. It differs from other land use models in that it does not attempt to predict whether or not residential development will occur. Instead, the buildout model assumes that development will occur. The main function of this model is to predict the location and intensity of that development.

The criteria used to estimate building costs and allowable densities were selected because both are measurable and spatially defined. Many factors, such as personal preference of construction materials, size, and view, contribute to the cost of building but are not predictably quantifiable. These were not considered in the analysis. Similarly, densities may be dictated by unpredictable factors such

as future subdivisions or planned unit developments. Because of this unpredictability, only existing landownership was evaluated. As important as measurable qualities are, it is also necessary that they be expressed geographically. Geographically-oriented information permits spatial analysis and map portrayal.

Estimating Relative Cost

The buildout model assumes that the relative cost of building a single family dwelling in the study area may be influenced by three principle factors; 1) proximity to roads, 2) slope percent, and 3) floodplain designation. All other factors, such as dwelling size and material costs, were held constant. The model assumes that the construction cost to a homeowner is least when the unit is built adjacent to a road or right of way. This assumption derives from the observation that existing infrastructure tends to promote development, an argument used extensively in growth management strategies (Mantell and others 1990).

The second assumption is that it costs less to build on level ground than on steep ground. Even on slopes greater than 25 percent, building is not entirely prohibited, it merely becomes more expensive to comply with the building codes and regulations. Special engineering designs require additional time and materials to construct, as do required off-site sewage disposal systems. Similar cost constraints hold true for floodplain designations. In the City of Missoula and Missoula County, floodplain development is allowed, but it is extremely costly to comply with the floodplain regulations. Property owners must demonstrate that structures will not significantly increase flood velocities or depths or alter stream

courses (City of Missoula, 1991).

Proximity to roads was calculated by digitizing existing roads and rights of way within the study area and converting the vectors to a raster image. The distance of each grid cell from the nearest road was then calculated. Finally, the distances were divided into four classes based on quarter-mile intervals. Each class was assigned a numeric value. Slope percent values were also divided into four classes and a numeric value was assigned to each class. Table 7 lists the classification for distance to roads and slope and the corresponding numeric values for each class.

Table 7 -- Road distance and slope classification.

ROAD DISTANCE CLASS	NUMERIC VALUE	SLOPE CLASS	NUMERIC VALUE
0 - .25 mile	4	0 - 8%	4
.26 - .50 mile	3	9 - 15%	3
.51 - .75 mile	2	16 - 25%	2
>.75 mile	1	>.25%	1

Relative costs of building were estimated for each grid cell by combining the values of each criterion class. A matrix was constructed to determine the range of values possible by multiplying the numeric value of the road distance class with the numeric value of the slope class. The values ranged from 1 to 16. This range was divided into three classes, and each class was assigned a rank reflecting the relative cost of building. Areas designated as 100-year floodplain by the U.S. Federal Emergency Management Agency (1988) were assigned the highest cost rank. Figure 10 shows the study area ranked on the basis of relative cost of building.

Estimating Allowable Density

Allowable density refers to the number of dwelling units per acre permitted within a residential zoning district (Kelly 1988). The study area is composed of seven zoning districts, each with its own density allocation. The majority of the study area lies within a C-A1 designation, which permits 1 dwelling unit per forty acres. Table 8 lists the zoning districts and the allowable densities. A zoning map is presented in Figure 11.

Table 8 -- City and County zoning applied to the Rattlesnake Valley and corresponding density values.

Zone	Description (Jurisdiction)	Allowable density	Density Value (dwelling unit/acre)
RR-1	Urban Residential (City)	Five dwelling units/acre	5
R-1	Urban Residential (City)	Four dwelling units/acre	4
C-RR3	Suburban Residential (County)	Four dwelling units/acre	4
C-RR2	Suburban Residential (County)	Two dwelling units/acre	2
C-RR1	Suburban Residential (County)	One dwelling unit/acre	1
C-A1	Resource Land (County)	One dwelling unit/forty acres	.025
P-1	Parks and Open Space (City)	No development allowed	0

Allowable densities were calculated on a per-property basis by multiplying the acreage of each property by the corresponding density value for the zoning district in which that property occurs. The resulting dwelling unit value represents the number of dwelling units that could be built on the property. Because a grid cell measures 10,000 square feet, approximately the size of a typical single family house and surrounding living space, a single grid cell corresponds to a single dwelling unit. The number of dwelling units that could be constructed on a

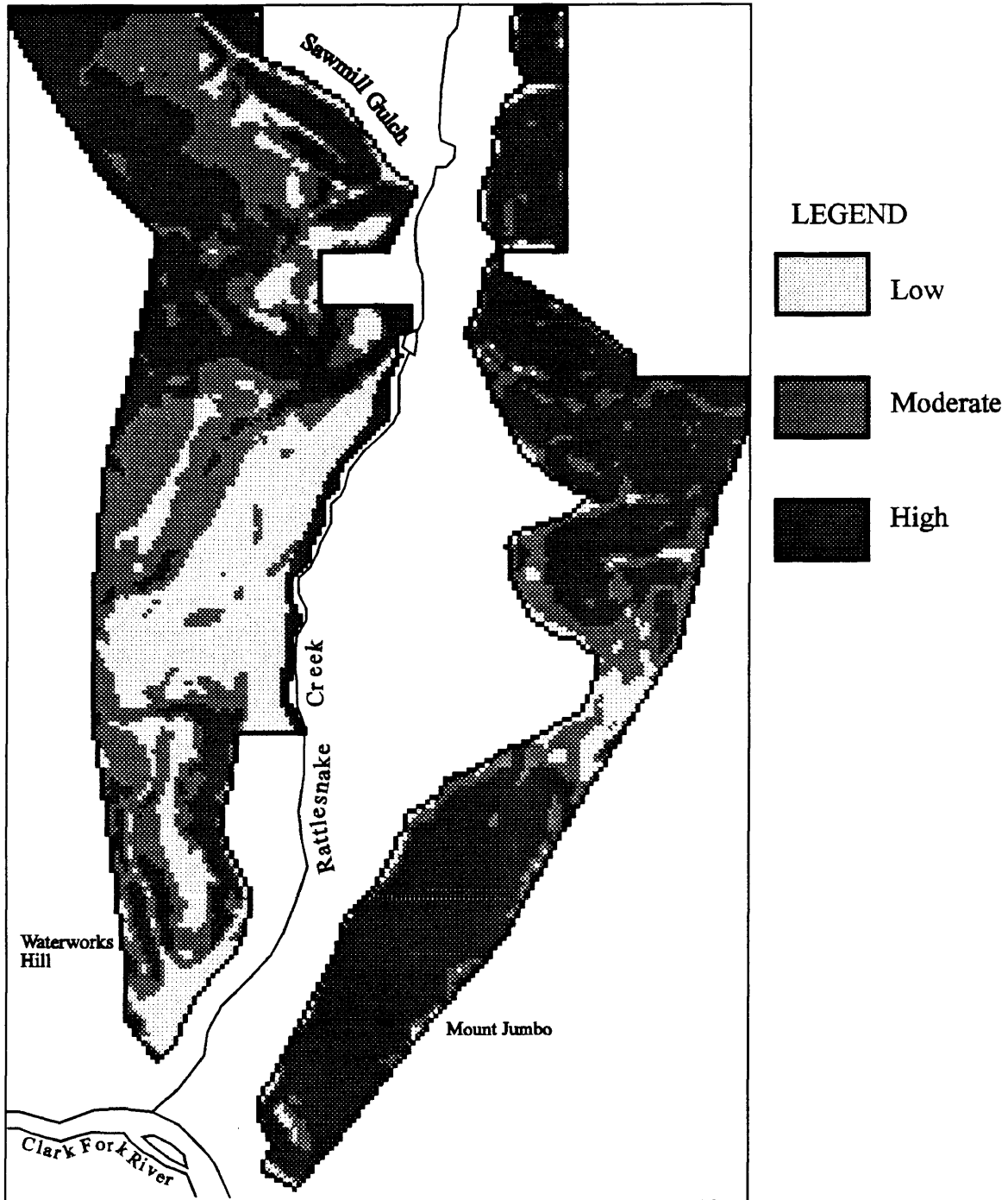
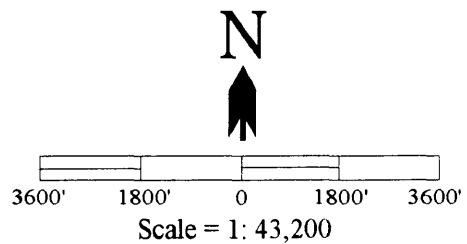


Figure 10. Relative cost of building ranks, Rattlesnake Valley.



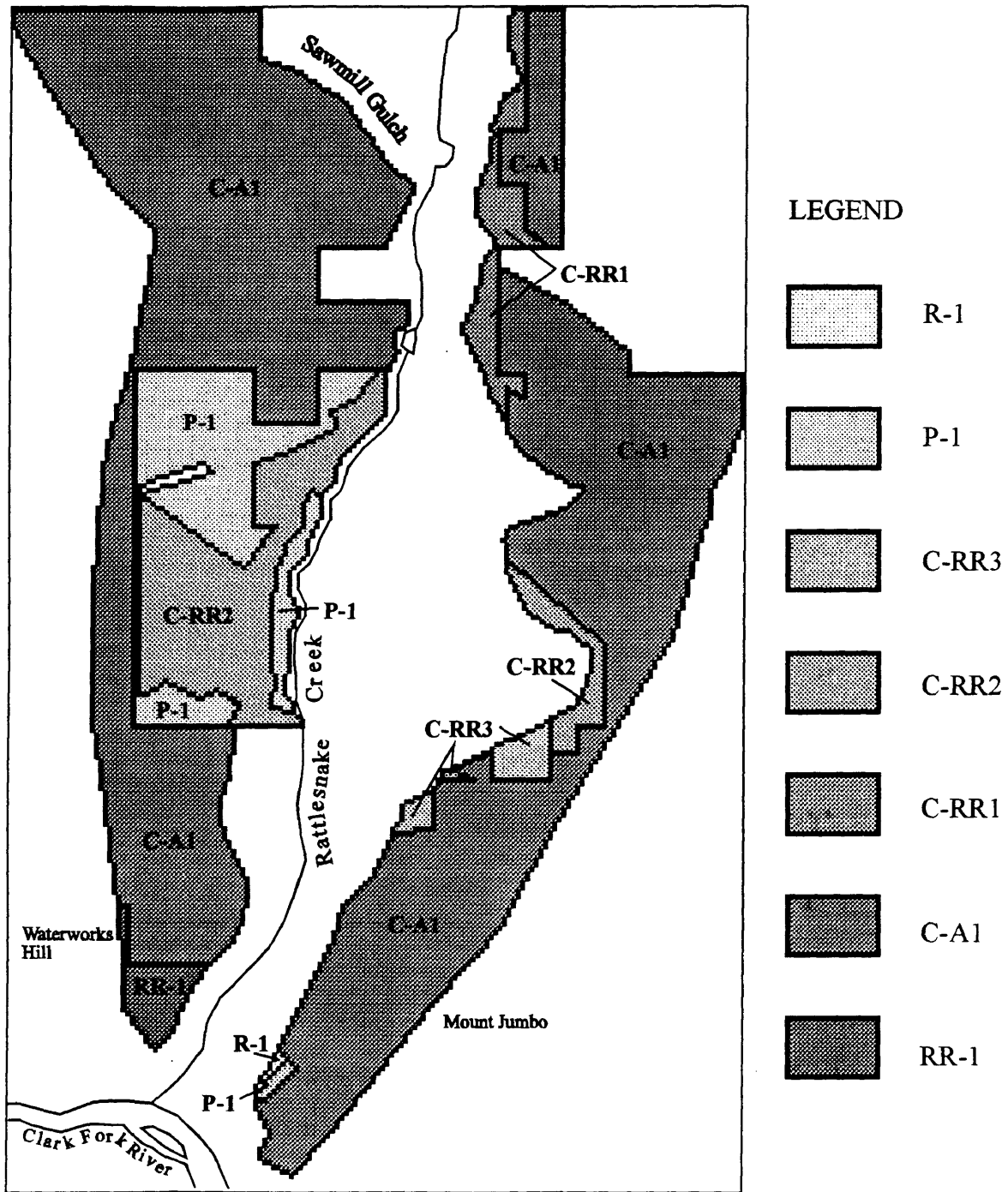
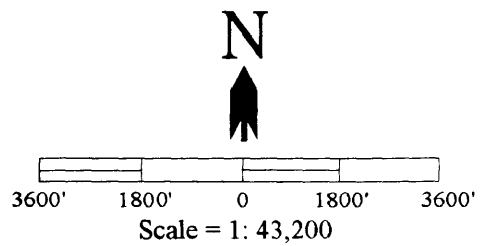


Figure 11. City and County zoning designations, Rattlesnake Valley. Source; City of Missoula 1992.



property is represented by the same number of grid cells.

The final step in the allowable density calculation was to determine the probability that a dwelling unit would be built in a each grid cell. Probabilities for every grid cell in each property were calculated by dividing the number of grid cells in a particular property which could be developed (n) by the total number of grid cells in that property (N). The resulting probabilities provide an index indicating the likelihood that residential development will occur based on allowable densities (n/N). The probabilities ranged from 0.1 percent to 100 percent. These values were further subdivided into three density probability ranks; high, medium and low. Figure 12 shows the density probability ranks for individual properties in the study area. Property owned by Montana Power Company, Mountain Water Company, and the City of Missoula were assigned a zero density probability. Fully developed properties which are partially overlapped by the study area were also assigned a zero density probability.

Estimating Development Potential

To complete the buildout model, the relative cost values for each grid cell were multiplied by the corresponding density probability values. The resulting values ranged from one to nine. This range was then divided to create three ranked classes of development potential. Values of one or two, represent a situation where both buildout factors are ranked low or one is ranked low and the other moderate. This corresponds to a low development potential. A moderate development potential results when both factors rank moderate or one is low and

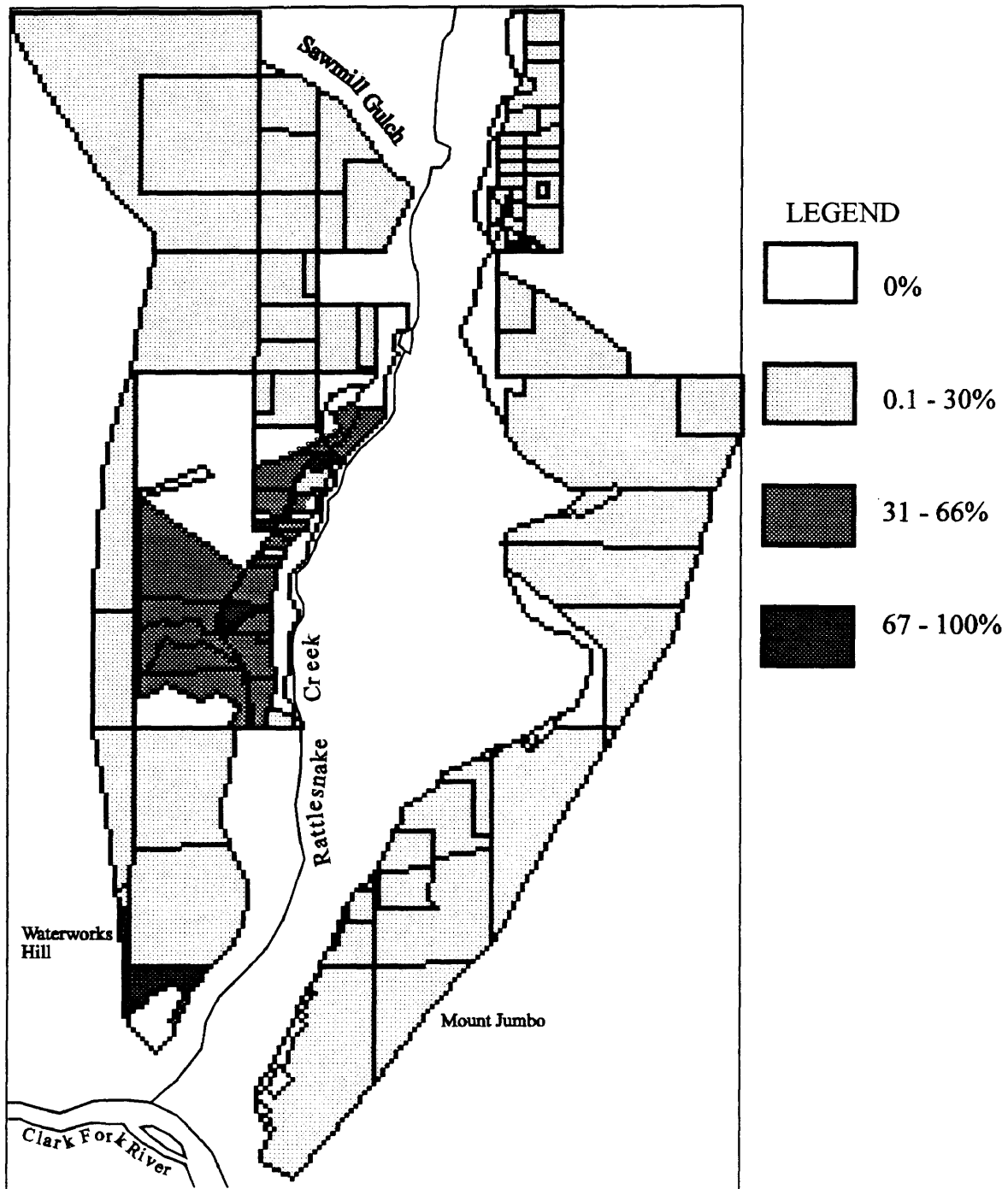
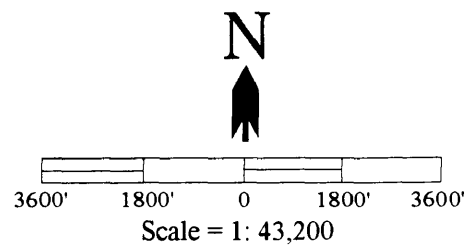


Figure 12. Density probability ranks, Rattlesnake Valley.



the other is high. The highest development potential results when at least one factor is ranked high and the other moderate or both factors are ranked high.

Figure 13 shows the study area ranked for development potential.

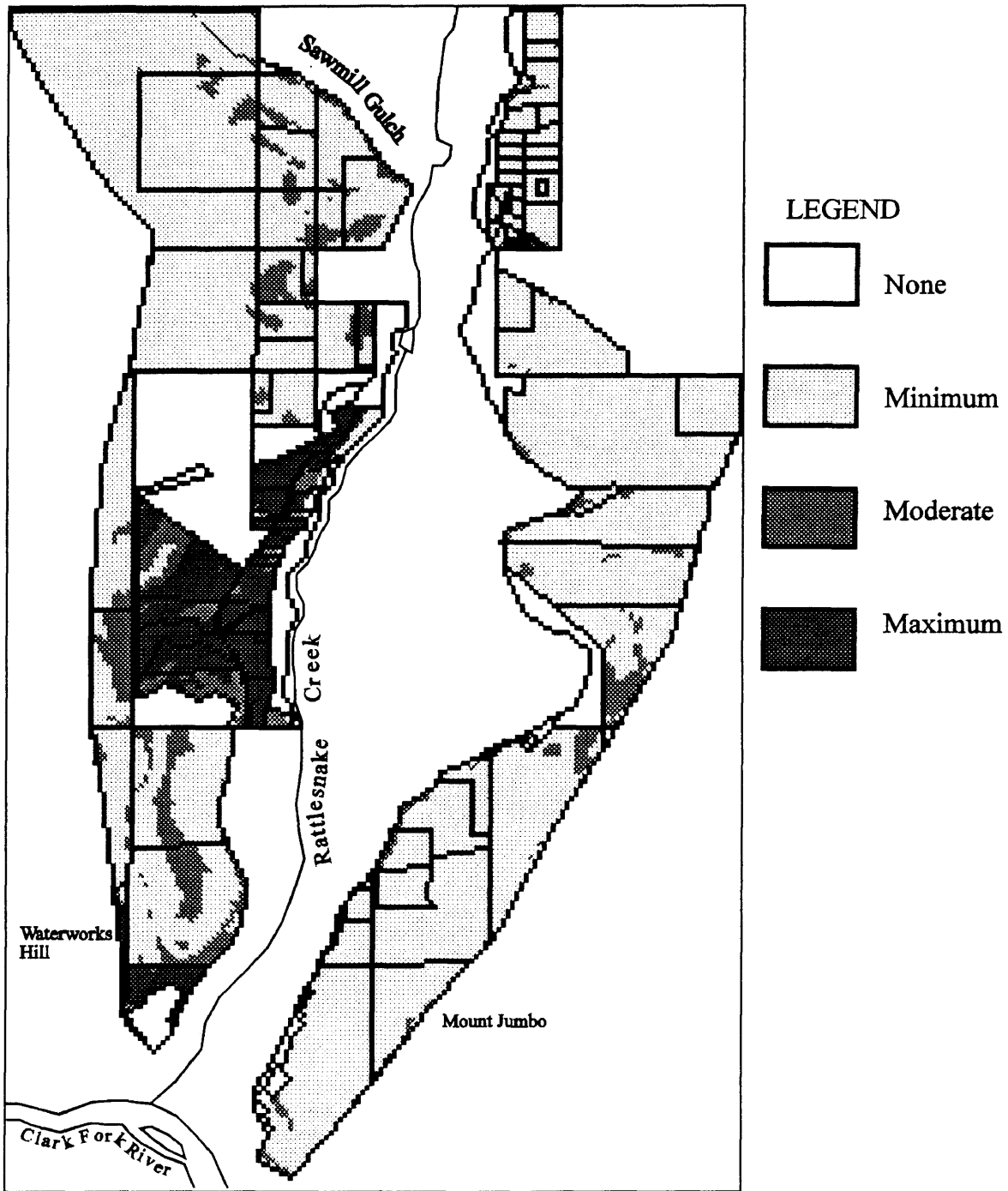
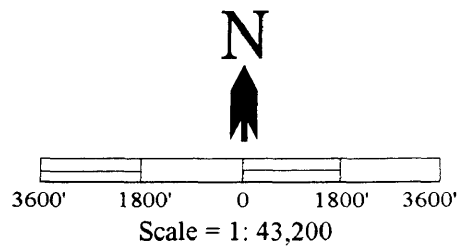


Figure 13. Development potential ranks, Rattlesnake Valley.



CHAPTER V

PREDICTING POTENTIAL CONFLICTS

The term suitability implies a compatibility between land and its corresponding use. The highest rank of suitability infers that the land can accommodate, without negatively affecting public health and safety or increasing building costs, the greatest intensity of the proposed use. Alternatively, a low ranking of suitability implies the greatest potential for negative consequences or conflicts. In order to assess the potential for conflicts, projected land use must be compared with land suitability.

Ranks of development potential generated by the buildout study for each grid cell represent the intensity of projected residential land use. The numeric values for development potential ranks were compared, grid cell by grid cell, with the numeric values for the three suitability maps. Assessment of conflict potential was based on this comparison. The criteria by which conflict potential was determined were:

- No conflict potential: - Areas where no development is projected.
- Low conflict potential: - Areas in which suitability is good and development potential is high, medium or low, or
- Areas in which suitability is marginal but development potential is low.
- Moderate conflict potential: - Areas in which suitability is marginal and

development potential is moderate, or
 - Areas in which suitability is poor and development potential is low.

High conflict potential:
 - Areas in which suitability is poor and development potential is moderate or high, or
 - Areas in which suitability is marginal and development potential is high.

Map comparison was performed using the cross-tabulation function in IDRISI. The grid cell values of one map were compared to those in a second map and a third map was produced in which a unique numeric value was assigned to each possible combination. The resulting combination values represent the conflict criteria described above. The final step in estimating conflict was to subdivide the range of combination values into three ranks. Results of the cross-tabulation for each suitability analysis are provided in Appendix A.

Discussion of Results

Slope

A map ranking potential conflicts between slope suitability and development potential is presented in Figure 14. The map shows that only moderate potential conflicts exist in most of the study area. This result is misleading because much of the area is underlain by slopes 25 percent or greater. Slopes this great were previously classified as poorly suited for residential use. The final output for the potential conflict, however, takes into account the corresponding low development potential. According to the rules outlined above, areas in which slope suitability is

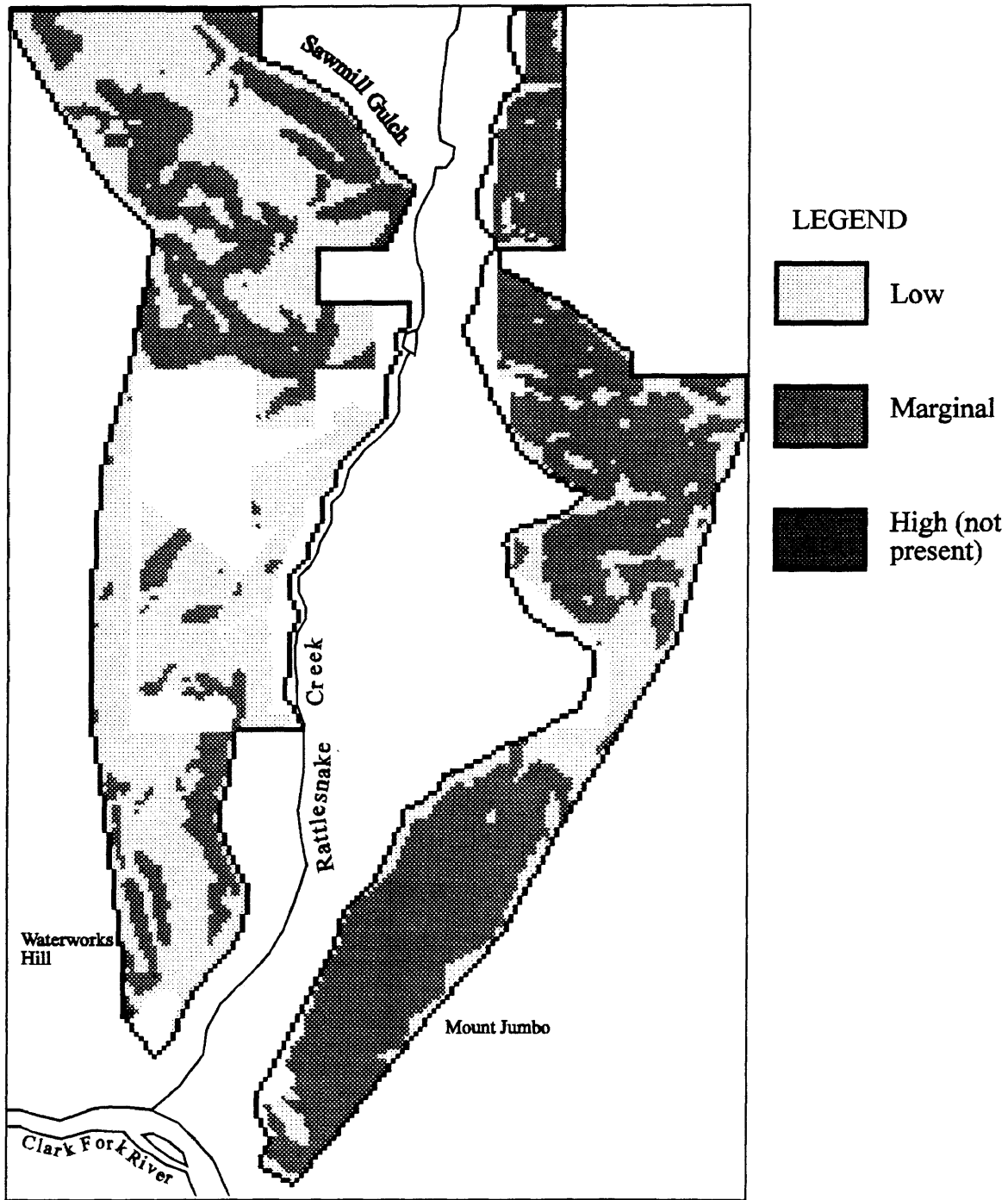
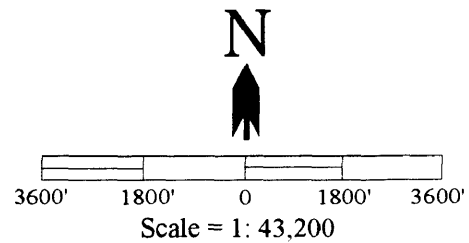


Figure 14. Potential conflict ranks; slope suitability and development potential, Rattlesnake Valley.



poor but development potential is low are ranked moderate.

The remaining portion of the study area is ranked low for potential conflicts. This indicates that these areas are ranked good (0-15 percent) for slope suitability at any level of development potential, or ranked marginal (15 - 25 percent) at low development potential.

Drainage

Most of the study area is underlain by soil units which produce moderate to rapid runoff and are highly to moderately permeable. These conditions typically provide adequate drainage. The exceptions are clay-rich soils derived from Tertiary sediments. The clay content in these soils, coupled with the low slopes on which most occur, cause these areas to be poorly drained. These soils tend to be present in areas ranked moderate to high for development potential. Consequently, the potential for conflict is high. Ranking for potential conflict between drainage suitability and development potential is shown in Figure 15.

Slope Stability

Potential conflicts are indicated within areas underlain by existing landslides or by material susceptible to failure. The conflict is greatest where these conditions exist and slopes exceed 25 percent. The conflict potential also reflects the high development potential for these areas. As with drainage, there is a strong negative correlation between slope stability suitability and development potential. Consequently, the potential for conflicts is great in some areas. Figure 16 shows

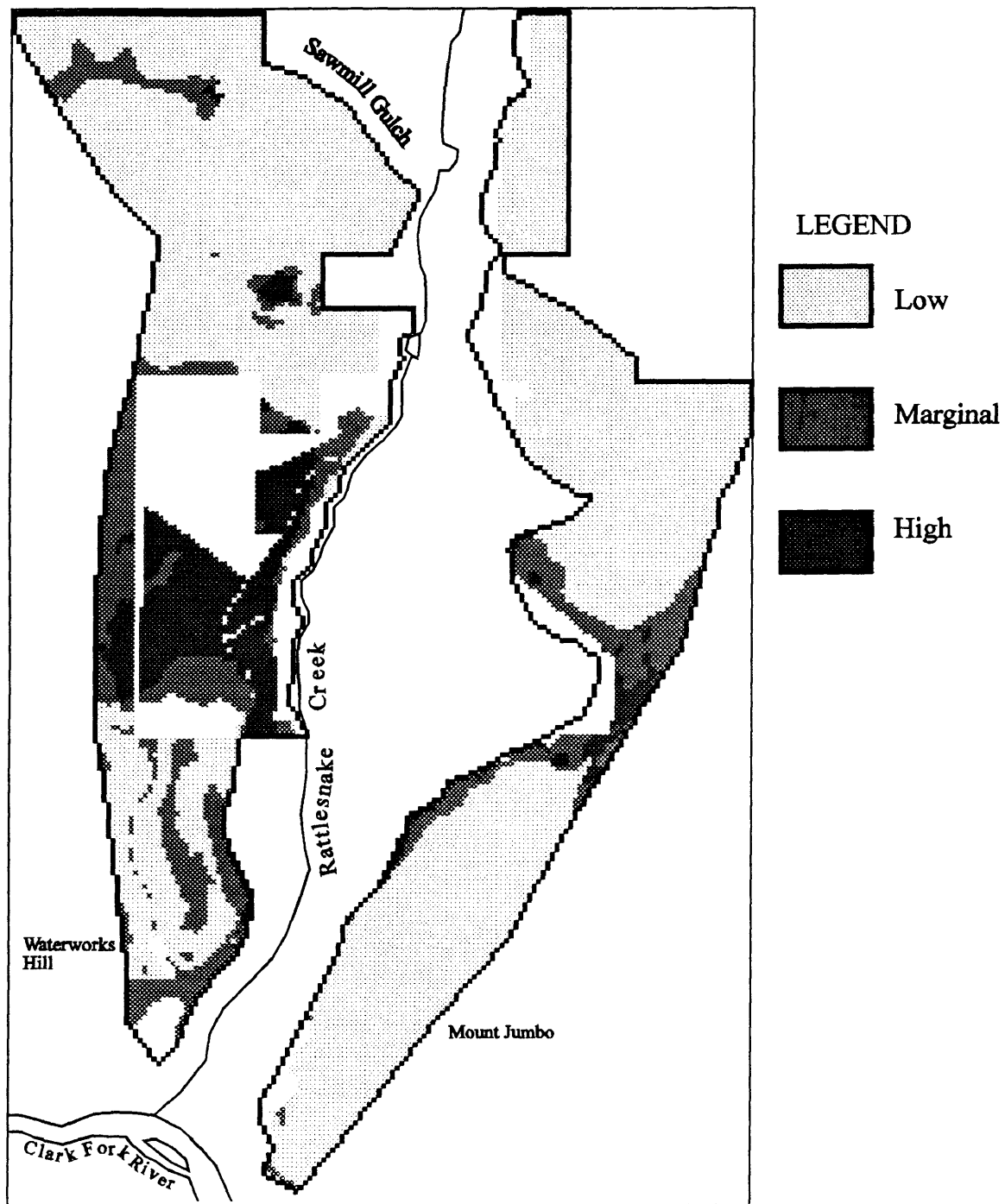
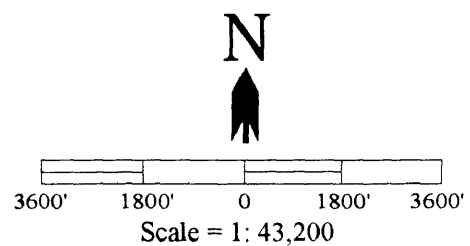


Figure 15. Potential conflict ranks; drainage suitability and development potential, Rattlesnake Valley.



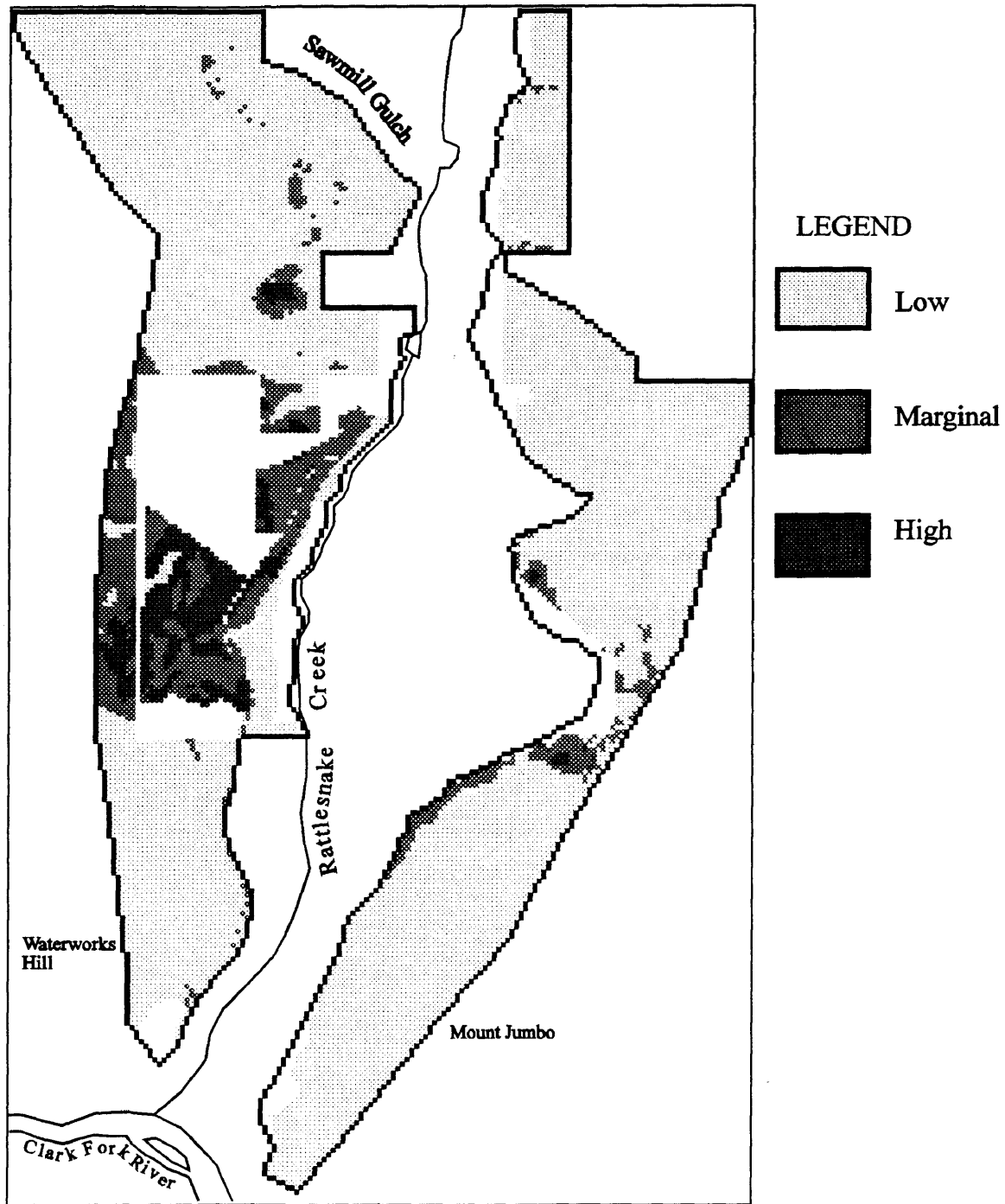
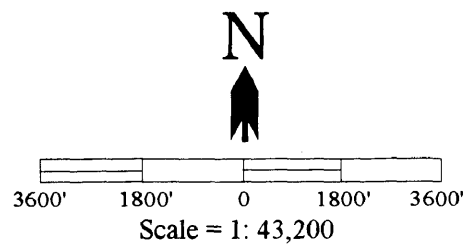


Figure 16. Potential conflict ranks; slope stability suitability and development potential, Rattlesnake Valley.



the ranking for potential conflict between lands ranked for slope stability suitability and development potential.

Interpretation

Current zoning will permit high density development in some areas that are marginally or poorly suited for residential use. The building costs incurred by developing these areas are anticipated to be high relative to the costs of building in other areas. Similarly, the risk to public health and safety is increased.

Many suitable sites exist within the study area which have the capacity to provide level building sites, adequate drainage, and stable foundation conditions, but few offer the advantage of all three. Some sites, which emerge as appropriate from the standpoint of slope, are not conducive to adequate drainage or stable foundations. This inconsistency is particularly true on or near the large landslide which dominates the central portion of both the East and West Rattlesnake. Here the land was reduced by slumping and weathering of clay-rich soils to flat ridges, swales and gentle slopes. If slope were the only constraint, this area would satisfy building requirements. However, the underlying materials are poorly suited for building with regard to other constraints of drainage and slope stability. The results of the three conflict assessments are difficult to combine because the significance of each is lost in the synthesis.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The ability to predict conflicts may help evaluate the risk to public health and safety and costs to society resulting from land development. Absolute predictions, however, are difficult when considering a large number of factors. The method presented in this study substitutes nominal ranking of potential conflicts for absolute predictions. By comparing development potential and land suitability, the study area was ranked according to the severity of potential conflicts.

Land suitability ranks for the Rattlesnake Valley, were determined for certain conditions favorable to residential development, specifically, level building sites, adequate drainage, and stable foundation conditions. The quality of these conditions determines the potential for damage to property or risks to public health and safety or both. Attributes of slope, soil, and geology were analyzed to rank the suitability of the study area with regard to slope, drainage, and slope stability.

The three suitability analyses identified some areas that are more appropriate than others for residential development. The results of the drainage and slope stability analyses correlate well with each other. This is due, in part, because the some of the same factors which influence drainage behavior also control slope

stability. Slope suitability results, however, do not correlate well with the other two analyses due to opposing factors. Steep slopes, which decrease slope suitability, tend to improve drainage and, within the study area, are often associated with more stable material.

Residential buildout for the Rattlesnake Valley was determined by combining building costs with density allowances. The relative cost of building was estimated from the slope of the building site, the distance of the site from an existing road or right of way, and proximity to the floodplain. Densities were initially calculated for each property using current zoning density allowances. The probability that a dwelling unit would be constructed at any given location was determined using the property density allowances. The buildout model indicates that most future development in the study area will occur on or adjacent to the valley bottom, near existing roads.

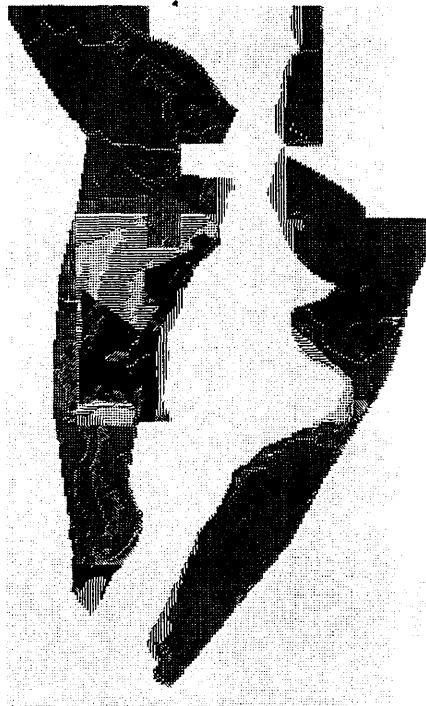
Future conflicts may result when building occurs on unsuitable land. The severity of these conflicts depends on the number of dwelling units and the corresponding suitability rank. Zoning contributes significantly to the outcome of conflict assessment because it is a major factor used to model development potential. The results of the three conflict assessments suggest that existing zoning accounts for slope conditions but does not consider drainage or slope stability conditions.















The opportunity exists to revise zoning in the Rattlesnake Valley because a final zoning proposal has not yet been adopted. The suitability analyses presented

in this study provide objective criteria necessary to develop zoning districts that are more land sensitive. A comprehensive analysis is required however, that should examine additional development constraints and critical landscape qualities before implementing zoning.

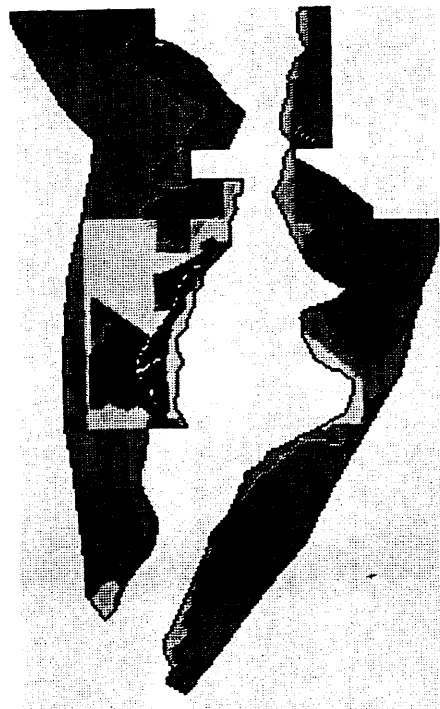
APPENDIX
















Cross tabulation between slope stability suitability ranks and development potential ranks. Values on left were divided into three conflict potential classes: 1-4 = no conflict; 6, 7, 10, and 13 = low conflict; 5, 9, and 12 = moderate conflict; 8 and 11 = high conflict.



				
1:	0		0	
2:	1		0	
3:	2		0	
4:	3		0	
5:	1		1	
6:	2		1	
7:	3		1	
8:	1		2	
9:	2		2	
10:	3		2	
11:	1		3	
12:	2		3	
13:	3		3	

Cross tabulation between drainage suitability ranks and development potential ranks.
 Values on left were divided into three conflict potential classes: 1-5 = no conflict; 7, 8, and 12 = low conflict; 6, 11, and 14 = moderate conflict; 10 and 13 = high conflict.



















				
1:	0		0	
2:	1		0	
3:	2		0	
4:	3		0	
5:	0		1	
6:	1		1	
7:	2		1	
8:	3		1	
9:	0		2	
10:	1		2	
11:	2		2	
12:	3		2	
13:	1		3	
14:	2		3	

Idrisi

Cross tabulation between slope suitability ranks and development potential ranks. Values on left were divided into three conflict potential classes: 1-4 = no conflict; 6, 7, 10, and 13 = low conflict; 5, 9, and 11 = moderate conflict; 8 = high conflict.



			
1:	0 0		
2:	1 0		
3:	2 0		
4:	3 0		
5:	4 0		
6:	1 1		
7:	2 1		
8:	3 1		
9:	4 1		
10:	1 2		
11:	2 2		
12:	3 2		
13:	4 2		
14:	1 3		
	Press PgDn		

SELECTED BIBLIOGRAPHY

- Aronoff, Stan. 1991. Geographic Information Systems: A Management Perspective. WDL Publications, Ottawa, Canada. 294 pp.
- Birkeland, Peter W. 1974. Pedology, Weathering, and Geomorphological Research. Oxford University Press, New York. 285 pp.
- Brooks, Kenneth N., Peter F. Ffolliott, Hans M. Gregersen, and John L. Thames. 1991. Hydrology and the Management of Watersheds. Iowa State University Press, Ames, IA. 329 pp.
- Brown, Robert D. and William J. Kockelman. 1983. Geologic Principles for Prudent Land Use, A Decisionmaker's Guide for the San Francisco Bay Region. U.S. Geol. Survey Prof. Paper 496. 97 pp.
- Carson, M. A. and M. J. Kirkby. 1972. Hillslope Form and Process. University Press, Cambridge, MA. 475 pp.
- City of Missoula. 1986. "South Hills Comprehensive Plan." 26 pp. Photocopied.
- _____. 1986. "Subdivision Regulations." 97 pp. Photocopied.
- _____. 1988. "Rattlesnake Valley Comprehensive Plan Amendment." 44 pp. Photocopied.
- _____. 1990. "Missoula Urban Comprehensive Plan." 63 pp. Photocopied.
- _____. 1991. "Floodplain Regulations." 30 pp. Photocopied.
- _____. 1992a. "Rattlesnake Valley Comprehensive Plan Amendment Limited Scope Update." 34 pp. with maps. Photocopied.
- _____. 1992b. "Missoula Municipal Code." Book Publishing Company, Seattle, WA.
- City and County of Missoula. 1991. "Missoula City County Health Department Regulations." Photocopied.

Cooke, R. U. and J. C. Doornkamp. 1974. Geomorphology in Environmental Management. Oxford University Press, Ely House, London. 413 pp.

Dbase IV, Rel. 2.0. Borland Corporation,

Dunne, Thomas and Luna B. Leopold, 1978. Water in Environmental Planning. W. H. Freeman and Co., USA. 818 pp.

Dutton, Barry. 1981. Soil Interpretations for Urban-related Developments in Western Montana. U.S. Dept. of Agriculture, Soil Conservation Service. 38 pp.

Federal Emergency Management Agency, 1988. Flood Insurance Rate Maps, Missoula County, Montana.

Hammond, Robert and Patrick McCullagh. 1989. Quantitative Techniques in Geography, an Introduction. Oxford University Press, Oxford, England. 364 pp.

Haring, Lloyd L., John F Lounsbury, and John W. Frazier. 1992. Introduction to Scientific Geographic Research. 4th ed., WCB Publishers, Dubuque, IA. 196 pp.

Habeck, James R. 1984. "Vegetation of the Missoula Area." University of Montana, Missoula, Montana. p 10 - 61. Photocopied.

Hills, G. Angus. 1961. The Ecological Basis for Land Use Planning. Ontario Department of Lands and Forests, Toronto. Research Report No. 46. 204 pp.

Hopkins, Lewis D. 1977. "Methods for Generating Land Suitability Maps: A Comparative Evaluation." *Journal of the Amer. Inst. of Planners*, 43(4): p 386 - 400.

IDRISI, Version 4.0. 1992. The Clark Labs for Cartographic Technology and Geographic Analysis, Clark University. Worcester, MA.

Kelly, Eric Damian. 1988. "Zoning." In The Practice of Local Government Planning, eds. Frank S. So and Judith Getzels, International City management Association, Washington, DC. p 251 - 284.

Kilbridge, Maurice D., Robert P. O'Block and Paul V. Teplitz. 1970. Urban Analysis. Division of Research, Graduate School of Business Administration, Harvard University, Boston MA. 332 pp.

Laird, Raymond T., Jeanne B. Perkins, David A. Bainbridge, James B. Baker, Robert T. Boyd, Daniel Huntsman, Paul E. Staub, and Melvin B. Zucker. 1979. "Quantitative Land-Capability Analysis." U.S. Geol. Survey, Prof. Paper 945. 115 pp.

Mantell, Michael A., Stephen F. Harper, and Luther Propst. 1990. Creating Successful Communities, A Guidebook to Growth Management Strategies. The Conservation Foundation, Island Press, Washington D.C.. 233 pp.

McHarg, Ian L. 1969. Design with Nature. Doubleday/Natural History Press, Garden City, NY. 197 pp.

McMurtrey, R. G., R. L. Konizeski, and A. Brierkrietz. 1965. "Geology and Groundwater Resources of the Missoula Basin, Montana." Montana Bur. Mines and Geology Bull. 47. 35 pp.

Nelson, W. H., and J. P. Dobell. 1961. "Geology of the Bonner Quadrangle, Montana." U.S. Geol. Survey Bull. 1111-F. p 189-235.

Nilson, Tor H., Robert H. Wright, Thomas C. Vlastic, and William E. Spangle. 1979. "Relative Slope Stability and Land-use Planning in the San Francisco Bay Region, California." U.S. Geol. Survey Bull. 944. 96 pp.

Poe, Forrest and Flossie Galland Poe. 1992. Life in the Rattlesnake. ArtText Publication Service, Missoula, Montana. 60 pp.

Quattro Pro, Ver. 4.0. Borland Corporation.

ROOTS Rel. 1.0. 1991. Laboratory for Computer Graphics and Spatial Analysis and the Unit for Housing and Urbanization, Graduate School of Design, Harvard University.

Sedway, Paul H. 1988. "District Planning." In The Practice of Local Government Planning, eds. Frank S. So and Judith Getzels, International City management Association, Washington, DD. p 95 - 116.

Steiner, Frederick. 1991. The Living Landscape: An Ecological Approach to Landscape Planning. McGraw-Hill, US. 356 pp.

Uniform Building Code. 1988. International Conference of Building Officials, Whittier CA. 926 p.

U. S. Department of Agriculture, Soil Conservation Service. 1975. National Soils Handbook. no page numbers.

- U. S. Department of Agriculture, Soil Conservation Service. 1983. "Missoula County Soil Survey." Unpublished report. 350 pp. Photocopied.
- U. S. Department of Agriculture, Soil Conservation Service. 1975. Urban Hydrology for Small Watersheds. Technical Release No. 55. 40 pp.
- Van der Poel, Washington. I. 1978 "A Reconnaissance of the Late Tertiary and Quaternary Geology, Geomorphology and Contemporary Surface Hydrology of the Rattlesnake Creek Watershed, Missoula County, Montana." M.S. Thesis, University of Montana. 85 pp. Photocopied.
- Weber and Associates. 1978 "Geology, Southwest Missoula Quadrangle, Montana." Unpublished report for City of Missoula, Planning Office. 4 plates.
- Westman, Walter E. 1985. Ecology, Impact Assessment, and Environmental Planning. Wiley, New York. 532 pp.