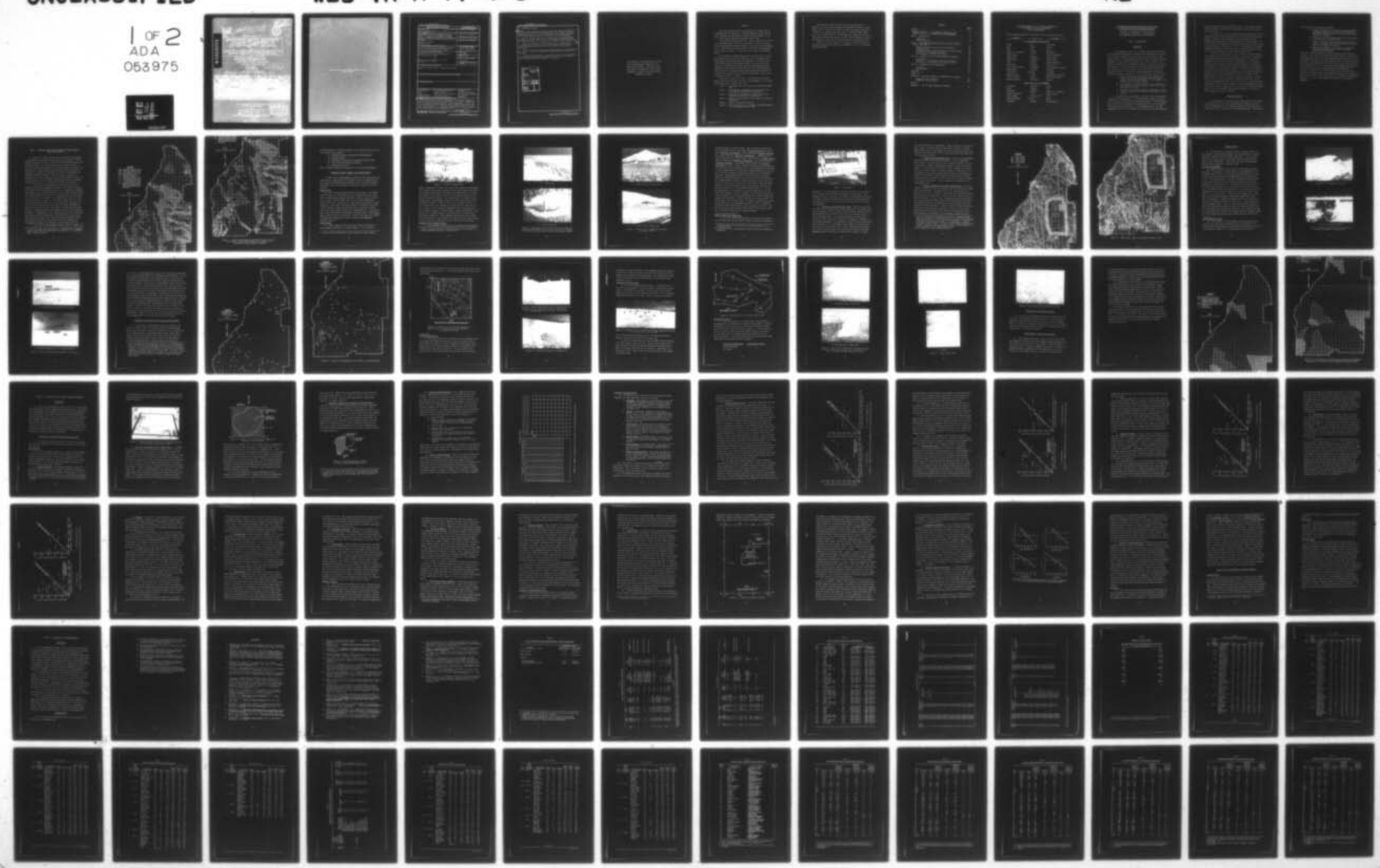
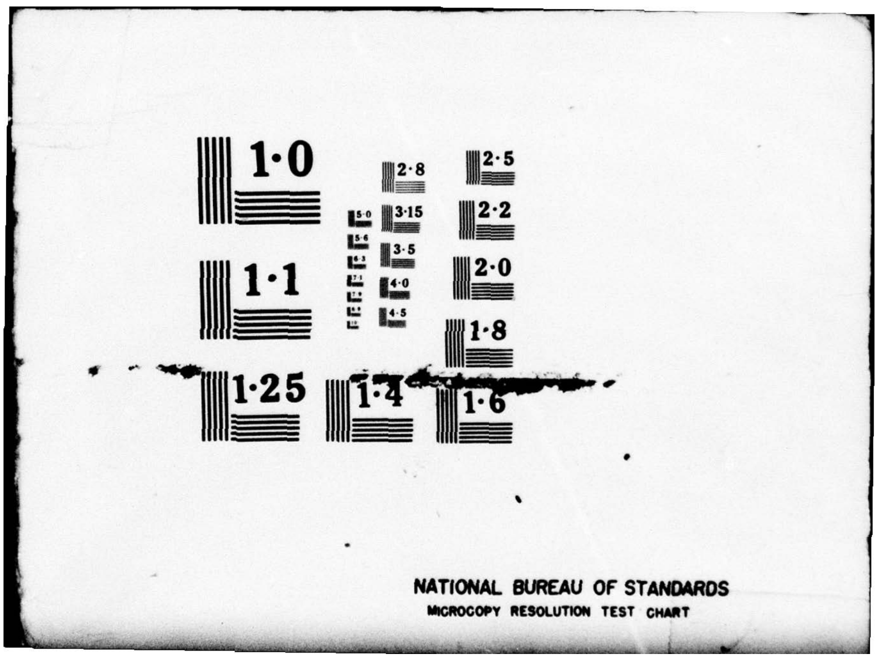
AD-A053 975   ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS   F/G 13/2
ENVIRONMENTAL BASELINE DESCRIPTIONS FOR USE IN THE MANAGEMENT O--ETC(U)
APR 78   A M REKAS, W L KIRK

UNCLASSIFIED   WES-TR-M-77-4-3   NL

1 OF 2
ADA
053975




1.0
2.8
2.5
3.15
2.2
3.5
2.0
4.0
1.1
4.5
1.8
1.25
1.4
1.6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

AD A053975

(14) WES-TR-M-77-4-3

(6)

TECHNICAL REPORT M-77-4

ENVIRONMENTAL BASELINE DESCRIPTIONS FOR USE IN THE MANAGEMENT OF FORT CARSON NATURAL RESOURCES,

Report 3,

INVENTORY AND ASSESSMENT OF CURRENT METHODS FOR RANGELAND CONSERVATION AND RESTORATION.

by

(10) Anthony M. B. Rekas, William L. Kirk

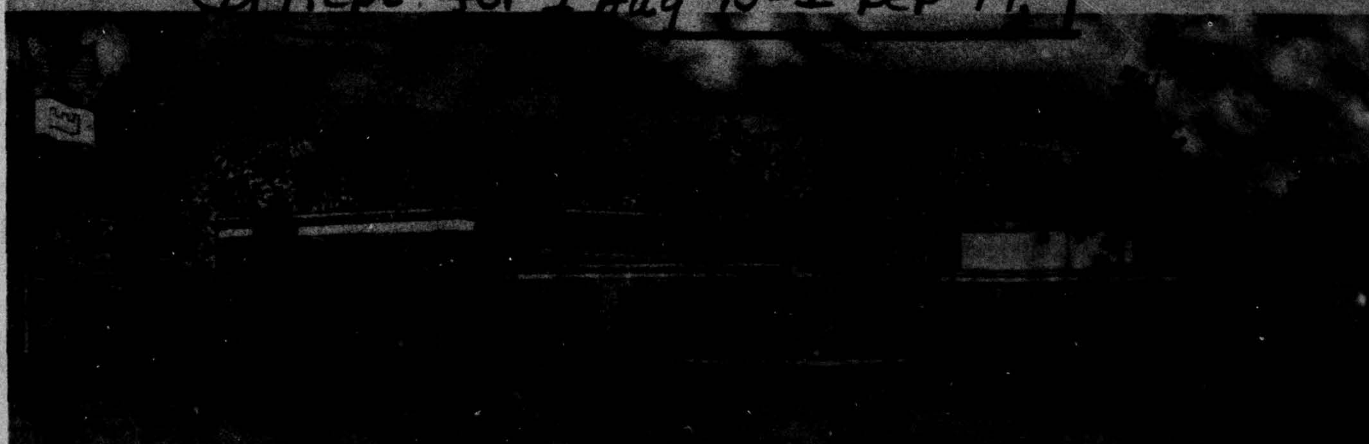
Mobility and Environmental Systems Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

(11) April 1978 (12) 131 p.

Report 3 of a Series

Approved For Public Release; Distribution Unlimited

(9) Rept for 1 Aug 75-1 Sep 77,



Prepared for Directorate of Facilities and Engineering
Fort Carson, Colorado 80913
and
Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

(16) Under Project 4A162121A896 Task [illegible] Work Unit [illegible]

(17)

038 100

JOB

Destroy this report when no longer needed. Do not return it to the originator.

14 WES-TR-M-77-4-3

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report M-77-4	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ENVIRONMENTAL BASELINE DESCRIPTIONS FOR USE IN THE MANAGEMENT OF FORT CARSON NATURAL RESOURCES; Report 3, INVENTORY AND ASSESSMENT OF CURRENT METHODS FOR RANGELAND CONSERVATION AND RESTORATION		5. TYPE OF REPORT & PERIOD COVERED Report 3 of a series 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Anthony M. B. Rekas William L. Kirk		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Mobility and Environmental Systems Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project 4A162121A896 Task 01, Work Unit 006
11. CONTROLLING OFFICE NAME AND ADDRESS Directorate of Facilities and Engineering Fort Carson, Colo. 80913 and Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE April 1978 13. NUMBER OF PAGES 124 15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Conservation	Environmental management	Natural resources
Dams	Erosion control	Reclamation
Debris	Erosion control by vegetation	Resource conservation
Debris barriers	Fort Carson, Colo.	Settling basins (Sediment)
Environmental data	Military installations	Soil erosion
		Vegetation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Environmental protection and enhancement of the natural resources of Army installations have become an integral part of the design, construction, operation, and maintenance activities on those installations. In 1975, the U. S. Army Engineer Waterways Experiment Station (WES) began a study to provide technical support (i.e. basic data and methodology) needed for the effective implementation of the rangeland conservation and restoration portions of the Fort Carson Land Use and Management Plan. (Continued)

Insert page

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued)

cont. This report describes the methods used by Fort Carson to control soil erosion, provides data on the areas where these control methods were used, presents data and results on the effectiveness of the restoration methods used at Fort Carson, and reviews soil erosion control methodologies.

The soil erosion control methods used by Fort Carson land management personnel include both vegetative, i.e. establishment of vegetative cover, and mechanical methods, i.e. construction of sediment basins and debris dams.

The data collected by the WES during the period 1 August 1975 to 1 September 1977 indicate that in the last six years 2078 acres of Fort Carson were seeded with grasses, 6179 acres were pitted, and 83 acres were ripped.

The WES identified and mapped 129 sediment basins and 14 debris dams on Fort Carson. A Fort Carson demonstration program using the debris dams is described.

The WES literature review of current soil erosion control methods indicates that there are additional vegetative control methods and mechanical control methods that could be applied to Fort Carson.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

PREFACE

The study reported herein was conducted from 1 August 1975 to 1 September 1977 by personnel of the Environmental Systems Division (ESD), Mobility and Environmental Systems Laboratory (MESL), of the U. S. Army Engineer Waterways Experiment Station (WES).

The work was authorized by LTC E. R. Hall, Directorate of Facilities and Engineering, Fort Carson, Colorado, as a part of the Fort Carson Long-Range Environmental Program. The overall Program Managers at Fort Carson were Mr. Durwood Davis (now retired), Land Management Branch (LMB), and Messrs. S. Ness, LMB, and M. Halla, Environmental Office.

The procedures and methodology used for acquisition of on-site environmental baseline data on vegetation, soils, topography, and meteorology were developed under the Department of the Army Project 4A762720A896 entitled "Environmental Quality for Construction and Operation of Military Facilities," Task 01, "Environmental Quality Management of Military Facilities," Work Unit 006, "Methodology for Characterization of Military Installations Environmental Baselines," sponsored by the Directorate of Military Construction, Office, Chief of Engineers (OCE), U. S. Army.

This report is one of a series of reports entitled "Environmental Baseline Descriptions for Use in the Management of Fort Carson Natural Resources." These reports are:

Report 1. Development and Use of Wildlife and Wildlife Habitat Data

Report 2. Water-Quality, Meteorologic, and Hydrologic Data Collected with Automated Field Stations

Report 3. Inventory and Assessment of Current Methods for Rangeland Conservation and Restoration

Report 4. Analysis and Assessment of Soil Erosion in Selected Watersheds

Report 5. General Geology and Seismicity

Report 6. Description and Use of a Computer Information System for Environmental Baseline Data

The study was conducted under the direct supervision of Messrs. H. W. West, Project Engineer, Environmental Simulation Branch (ESB), and J. K. Stoll, Chief, ESB, and under the general supervision of Messrs. B. O. Benn, Chief, ESD, and W. G. Shockley, Chief, MESL. Mr. A. M. B. Rekas and Dr. W. L. Kirk, ESB, were responsible for the field data collection and analysis of data on the restoration practices and vegetation. This report was prepared by Mr. Rekas and Dr. Kirk.

COL G. H. Hilt, CE, and COL J. L. Cannon, CE, were Directors of the WES during the study and report preparation. Mr. F. R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) AND METRIC (SI) TO U. S. CUSTOMARY UNITS OF MEASUREMENT

Units of measurement used in this report can be converted as follows:

Multiply	By	To Obtain
U. S. Customary to Metric (SI)		
inches	2.54	centimetres
feet	0.3048	metres
yards	0.9144	metres
miles (U. S. statute)	1.609344	kilometres
square inches	6.4516	square centimetres
square feet	0.09290304	square metres
square yards	0.8361274	square metres
acres	0.004047	square kilometres
cubic yards	0.7645549	cubic metres
cubic feet per second	0.02831685	cubic metres per second
pounds (mass)	0.4535924	kilograms
tons (short)	907.1847	kilograms
inches per hour	0.04234	centimetres per minute
feet per second	0.3048	metres per second
degrees (angular)	0.01745329	radians
Metric (SI) to U. S. Customary		
centimetres	0.3937007	inches
metres	3.280839	feet
kilometres	0.6213711	miles (U. S. statute)
square centimetres	0.1550	square inches
square metres	2.47105×10^{-4}	acres
square kilometres	247.105	acres
kilograms	2.204622	pounds (mass)

ENVIRONMENTAL BASELINE DESCRIPTIONS FOR USE IN THE MANAGEMENT OF FORT CARSON NATURAL RESOURCES

INVENTORY AND ASSESSMENT OF CURRENT METHODS FOR RANGELAND CONSERVATION AND RESTORATION

PART I: INTRODUCTION

Background

1. Army Regulation (AR) 420-74 entitled "Natural Resources-Land, Forest and Wildlife Management," states: "The Department of the Army, as an important occupier of Federal lands, has an obligation to the American people to act responsibly and effectively in natural resources management. This includes the obligation to restore, improve, and preserve through wise use management the natural resources of the lands and waters it controls. The Natural Resources Program prescribed by this regulation, and the military mission, need not and will not be mutually exclusive." The natural resources management objectives of the Natural Resources Program, as listed in AR 420-74, are as follows:

> a. Protect and conserve the watersheds and natural landscapes, the soil, the beneficial forest and timber growth, and the fish and wildlife as vital elements of an optimum natural resources program.
>
> b. Use and care for natural resources in the combination best serving the present and future needs of the United States and its people.
>
> c. Provide for the optimum ecological development of land and water areas and for controlled public access to such areas.

2. Implementation and management of the Fort Carson Environmental Program is the responsibility of the Environmental Quality Section of the Directorate of Facilities and Engineering (DFAE).[1] The Land Management portion of that program is the responsibility of the Land Management Branch, DFAE, and consists of two management plans: the Land Management Plan for the cantonment area, and the Land Use and Management

Plan for downrange training and maneuver areas. Soil and water conservation and attention to aesthetic requirements are an integral part of the latter plan.

3. In 1974, the U. S. Army Engineer Waterways Experiment Station (WES) began testing methodologies at Fort Carson for the detection and mapping of damage to surface vegetation due to vehicular traffic during training maneuvers. The study resulted in a description of the actual damage to the vegetation in terms of kilometres of vehicle tracks per square kilometre (intensity of use).[2] A second phase of fieldwork, designed to demonstrate field data collection methods developed under Project A896, was completed by a WES team in August 1975.

4. During the second phase of the fieldwork, it became apparent that the WES could provide direct support to Fort Carson in generating information and environmental baseline data needed to develop and implement the Fort Carson Land Use and Management Plan. A proposal, describing several tasks (including one pertaining to the evaluation and assessment of the Fort Carson restoration methods), was submitted to and accepted by the DFAE, Fort Carson. A major portion of the work proposed would provide baseline data for use in the range restoration, erosion control, and land management portions of the Land Use and Management Plan. Two of the reports listed in the preface, i.e. Reports 3 and 4, specifically address aforementioned portions of the Land Use and Mmanagement Plan. This report, Report 3, addresses range restoration, erosion control techniques, and land management procedures used at Fort Carson to minimize soil loss due to wind and water erosion. Report 4 is directed toward establishing the amount of soil loss at Fort Carson as a function of land use.

Purpose and Scope

5. The purpose of the work reported herein was to provide technical support (i.e. basic data and methodology) needed for the effective implementation of the rangeland conservation and restoration portions of the Fort Carson Land Use and Management Plan. This portion

of the plan has the following objectives:

<u>a</u>. Control of sheet and rill erosion by the establishment of permanent grasses (in areas where vegetation was destroyed by vehicle maneuvers) by pitting, pitting and seeding, and ripping.

<u>b</u>. Control of gully and channel erosion by the construction of sediment basins and debris dams.

<u>c</u>. Control of wind and soil erosion by limiting vehicle traffic to existing roads, in conjunction with pitting, pitting and seeding, and ripping.

<u>d</u>. Reduction of damage to trees, shrubs, and grasses by placing critical areas "off limits" to training maneuvers and bivouacking.

The scope of work performed by the WES relating to these objectives included: (a) a review of methods used by Fort Carson to control water- and wind-induced soil erosion, and identification and mapping of the areas where the control methods were applied (Part II), and (b) an evaluation of the effectiveness of the soil erosion control methods used by Fort Carson (Part III). The conclusions and recommendations, based on both the field study and a literature survey, are summarized in Part IV. A review of soil erosion control methods reported in the literature to identify those with potential for improving the effectiveness of soil erosion control operations at Fort Carson is presented as Appendix A. A list of range specialists consulted is included as Appendix B.

PART II: RANGELAND RESTORATION AND EROSION CONTROL METHODS USED AT FORT CARSON

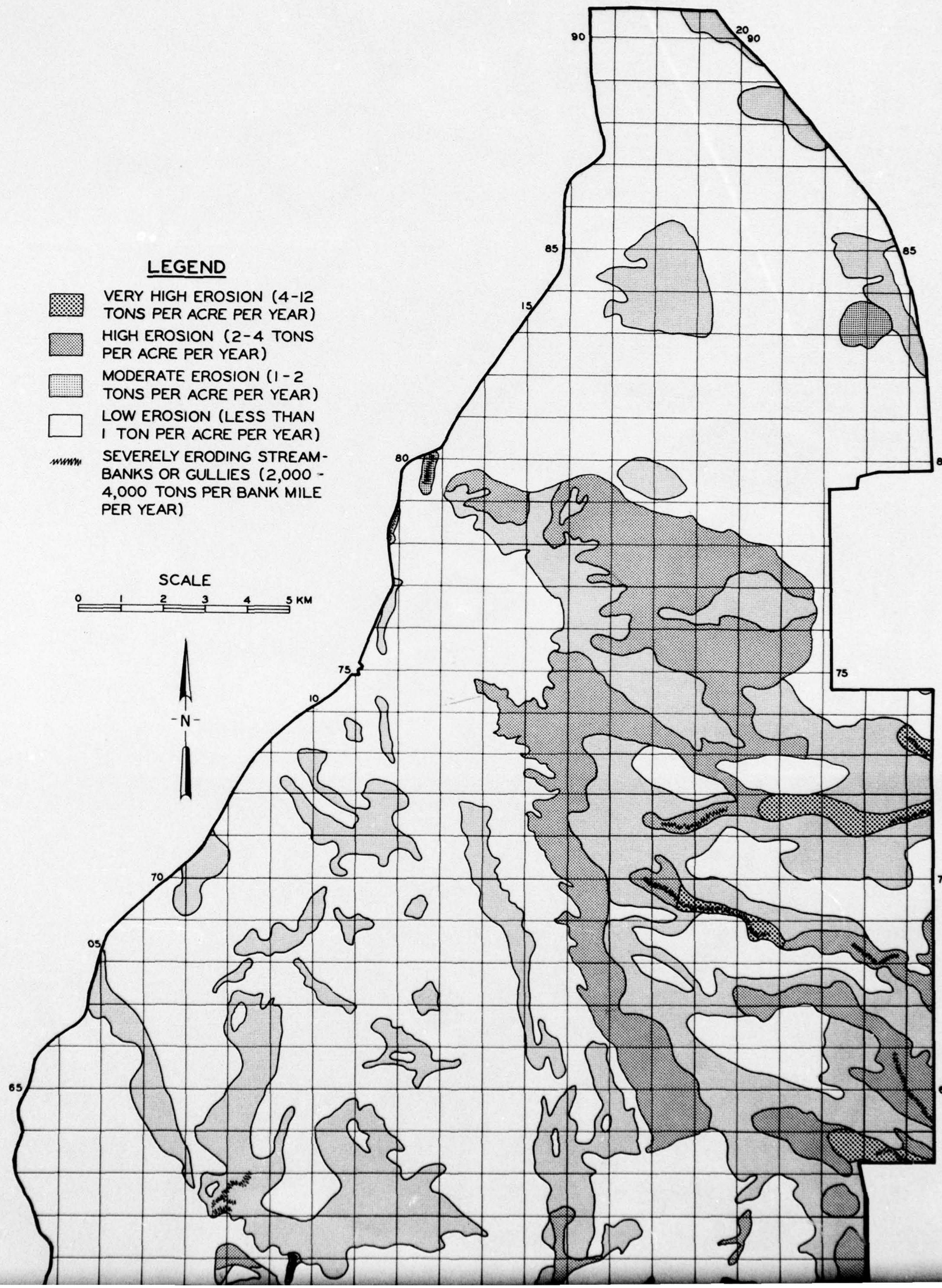
6. Erosion is defined as the process by which the land surface is worn away by the action of water, wind, ice, or gravity.[3] These elements usually erode soil at a slow and relatively uniform rate over thousands of years in a process referred to as "natural erosion." When the natural terrain surface is disturbed by man's activities (e.g. by wheeled or tracked vehicles during military training maneuvers), vegetation is destroyed, the exposed soil surface is disturbed, and drainage patterns are altered. These factors can contribute to increased soil erosion, especially in a semiarid climate like that of eastern Colorado. On Fort Carson, rainfall and wind are the primary erosion forces that act on disturbed and exposed soil surfaces.

7. In an effort to determine where the most severe erosion problems existed, land management personnel at Fort Carson requested that the Soil Conservation Service (SCS) (U. S. Department of Agriculture (USDA), Denver, Colorado) prepare an erosion map[4] showing areas on Fort Carson characterized by (a) a very high erosion rate (4-12 tons* of soil lost per acre per year), (b) a high erosion rate (2-4 tons of soil lost per acre per year), (c) a moderate erosion rate (1-2 tons of soil lost per acre per year), (d) a low erosion rate (less than one ton of soil lost per acre per year), and (e) eroding streambanks or gullies with soil loss rates of from 2000 to 4000 tons per bank mile per year. The SCS erosion map was completed in 1976 and is presented as Figure 1. Measurements of the individual areas on the SCS map show that 700 acres of Fort Carson have a very high erosion rate; 16,000 acres have a high erosion rate; 34,000 acres have a moderate erosion rate; 84,000 acres have a low erosion rate; and 30 bank miles of streambanks and gullies are eroding at the above-specified rate.

8. Since 1968 the Land Management Branch, DFAE, has applied the

---

* A table of factors for converting U. S. customary units of measurement to metric (SI) units and metric (SI) units to U. S. customary units is given on page 5.



LEGEND
VERY HIGH EROSION (4-12 TONS PER ACRE PER YEAR)
HIGH EROSION (2-4 TONS PER ACRE PER YEAR)
MODERATE EROSION (1-2 TONS PER ACRE PER YEAR)
LOW EROSION (LESS THAN 1 TON PER ACRE PER YEAR)
SEVERELY ERODING STREAM-BANKS OR GULLIES (2,000-4,000 TONS PER BANK MILE PER YEAR)
SCALE
0 1 2 3 4 5 KM
N
90
20
90
85
15
85
80
80
75
10
75
70
70
05
65
65

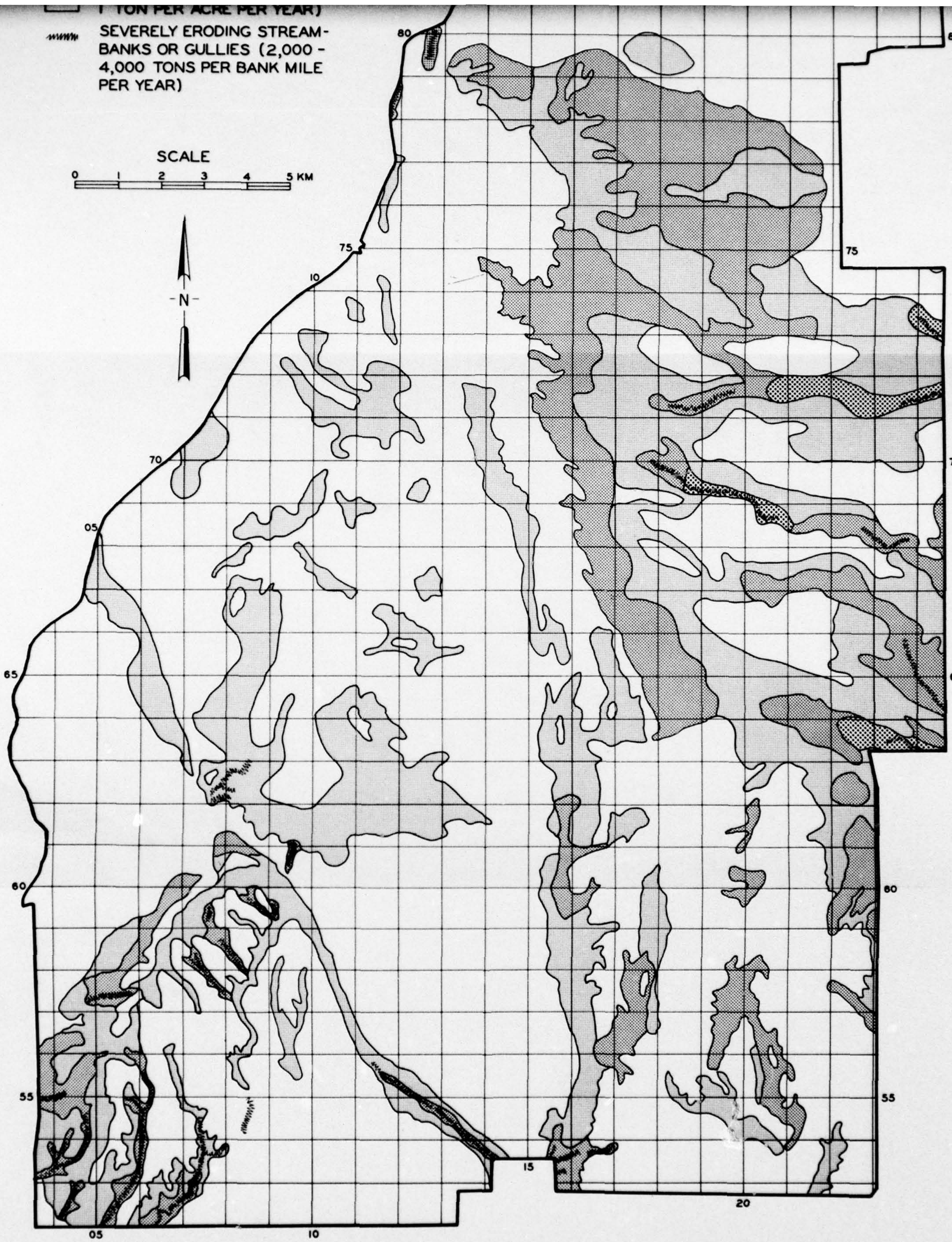


Figure 1. Erosion map showing existing erosion rates of soil on Fort Carson, Colorado (Map prepared by Al Elkins, Soil Conservation Service, Denver, Colorado)

following methods to restore vegetation cover conditions and to control soil erosion on Fort Carson:

- a. Rangeland pitting, ripping, and seeding methods.
- b. Sediment basins.
- c. Reshaping eroded areas and constructing debris dams.
- d. Diversions and floodwater spreaders.
- e. Restricted use areas.

These restoration methods are discussed in the following paragraphs.

Rangeland Pitting, Ripping, and Seeding Methods

9. Since 1969, land management personnel at Fort Carson have used range pitting, range ripping, and seeding of native and adapted perennial grasses to reestablish the vegetation cover in selected training areas where water- and wind-induced forces have caused soil erosion problems.

Range pitting

10. The pitting implement employed by Fort Carson is an A-frame pitter* (Figure 2), which consists of two rotating axles, each with a pair of eccentrically mounted disk blades. When the pitter is pulled over the land, the disk blades scoop out four shallow depressions (24 in. wide, 48 in. long, and 6 in. deep) that are spaced 60 in. apart (Figure 3). Fort Carson used range pitting to increase the retention of soil moisture in areas covered with native grasses and in areas that will later be seeded with native or adapted grasses. Pitted areas have a very rough surface and thus have the added value of discouraging wheeled vehicle traffic over the area. This is the least costly method of increasing vegetation cover that is used by land management personnel (Table 1).

Range ripping

11. Range ripping or deep chiseling is used by Fort Carson land management personnel for several purposes: (a) to shatter or

---

* Scranton Pitter, manufactured by Ace Industries, Lama, Colorado.

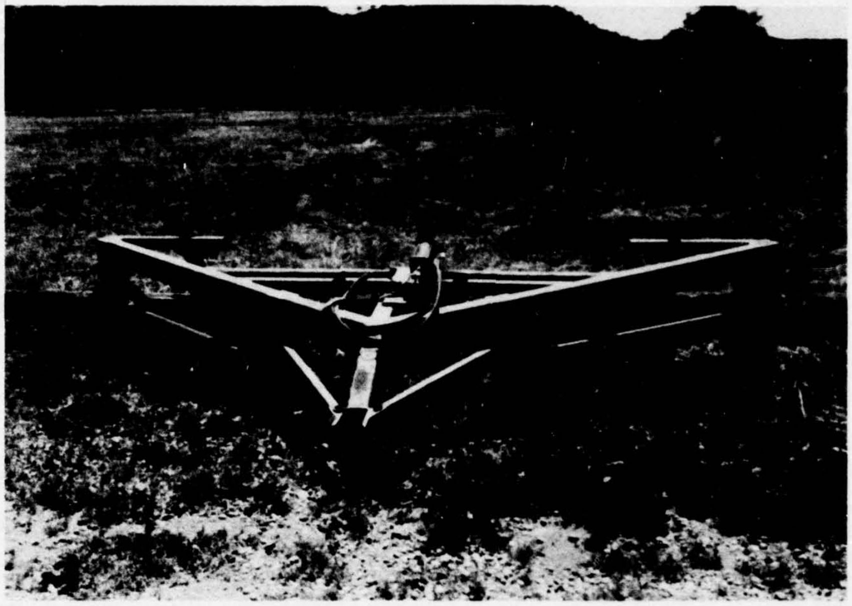


Figure 2. Scranton A-frame pitter

break up compacted soil layers that inhibit root growth and development; (b) to bring to the surface large dirt clods, which leaves a very deep and roughened surface that is resistant to wind erosion; (c) to intercept and store runoff water; and (d) to discourage crossing or use of the area by wheeled vehicles. Fort Carson uses a D-7 tractor that is equipped with a large drawbar having two or three large ripper teeth. The teeth can reach to a depth of 36 in. and are spaced from 12 to 24 in. apart on the bar. Usually, the teeth are set to till the full 36 in. unless the soil conditions (compacted, wet, underlying rock, etc.) restrict ripping to a shallow depth. Ripping is performed on the contour or in a zigzag pattern to trap runoff and to increase water infiltration (Figure 4). Land management personnel do not rip areas that are classed in a range condition of fair* or better, since pitting is less costly and is believed to be more effective in those areas.

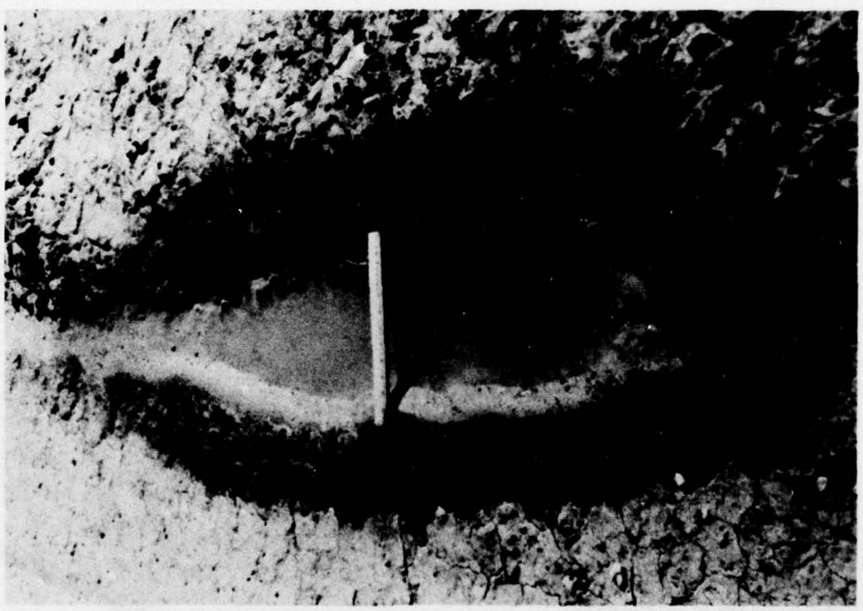
<u>Seeding native or adapted grasses</u>

12. Land management personnel have used both native and adapted

---

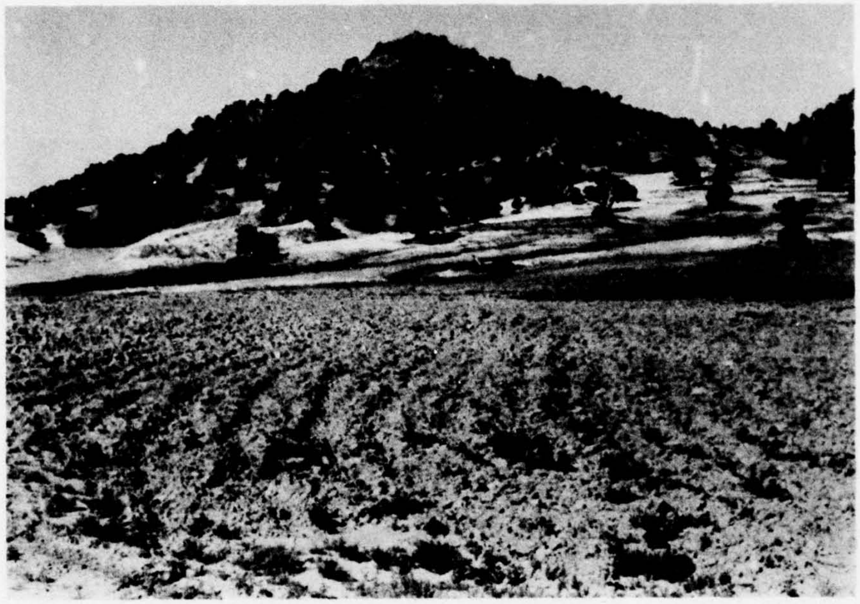
* Present vegetation production represents from 25 to 50 percent of potential maximum production for those areas.

a. Pitted area

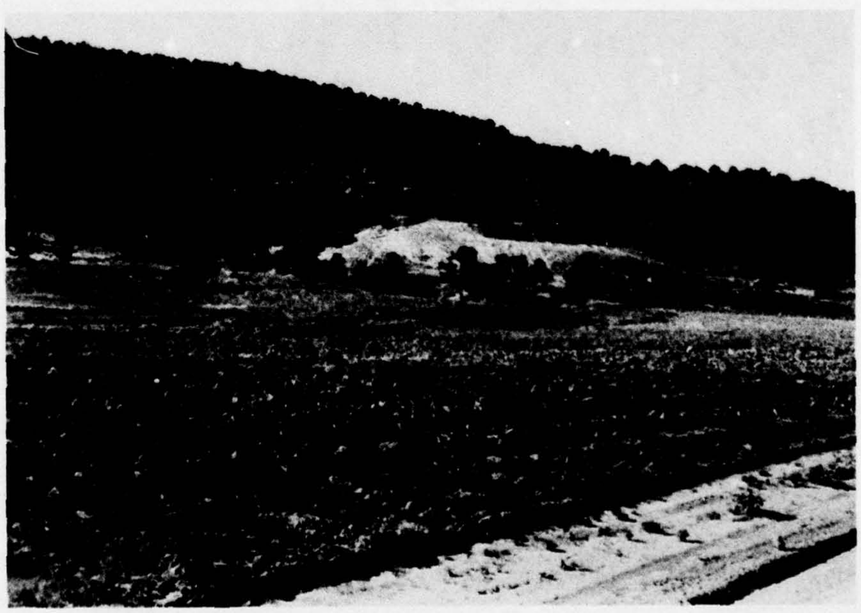


b. A 24- by 48-in. pit

Figure 3. Ground photo of pitted area (area 10 in Figure 6) showing effectiveness of pits for the collection and storage of rainfall and surface runoff (military coordinates 235635)



a. Southwest view of ripped area



b. West view of ripped area

Figure 4. Ground views of ripped area (military coordinates 095613)

perennial grasses for range seeding. Native perennial grasses that have been seeded include: blue grama (Bouteloua gracilis), side-oats grama (Bouteloua curtipendula), western wheatgrass (Agropyron smithii), and slender wheatgrass (Agropyron trachycaulum). Adapted perennial grasses that have been seeded include: Russian wildrye (Elymus junceus), pubescent wheatgrass (Agropyron trichophorum), and crested wheatgrass (Agropyron cristatum). One legume, yellow sweetclover (Melilotus officinalis), was also seeded. Both hand broadcasting and a mechanical seed drill were used to plant the seed. Hand broadcasting was employed in areas having shallow or rocky soils or exposed bedrock, or in areas where trees and boulders restricted the operation of the mechanical equipment. The mechanical drills (used by Fort Carson in pitted areas) are standard agricultural grain drills that have been modified for seeding perennial grasses. The drill, which is pulled by a farm tractor, consists of a large seed bin, seed funnels, furrow openers, a mechanical drive mechanism that controls the seed bin agitator, and drag chains mounted on a 20-ft wheeled frame* (Figure 5). The rate of seed planting is controlled by the tractor speed and size of the seed funnel openings. Twelve to eighteen rows of seeds are planted at a time, depending upon the desired spacing of the furrow openers, seed funnels, and drag chains. The SCS standards and specifications[5,6] for seeding rates, seed planting depth, row spacing, and grass seed purity are followed by the land management personnel. Costs of mechanical drilling and hand broadcasting of seed are compared in Table 1. Fort Carson also has recently acquired (March 1977) a Truax Grass Drill** that is currently being used for rangeland seeding.

Location and description of pitted, seeded, and ripped areas

13. In 1975, the WES determined the location of all the areas on Fort Carson that had been pitted, ripped, and seeded and prepared a

---

* Massey-Ferguson Drill, manufactured by Massey-Ferguson, Inc., Des Moines, Iowa.

** Truax Grass Drill, manufactured by Truax Corporation, Minneapolis, Minnesota.

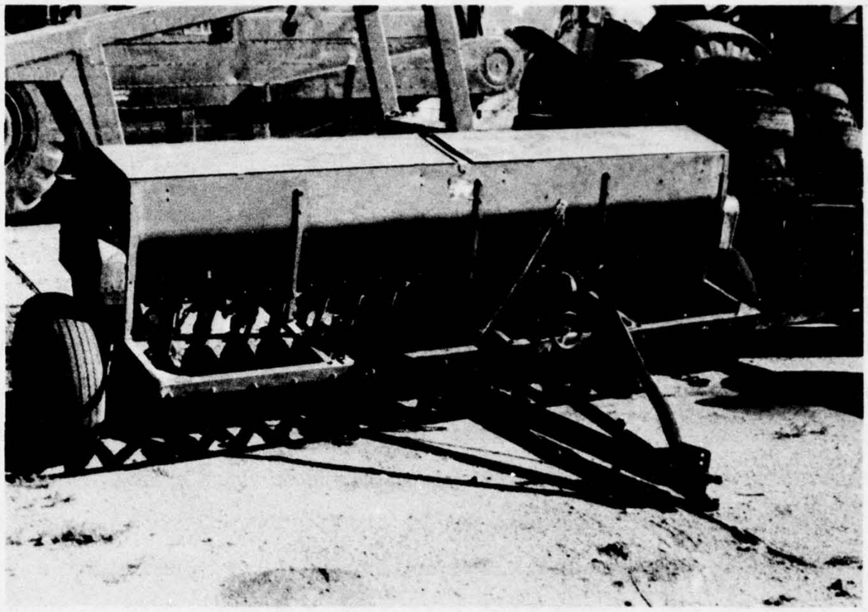


Figure 5. Seed drill

description of the environmental conditions (surface soil classifications, average elevations, and slope ranges) in those areas. Land management personnel furnished the vegetation establishment data (dates of pitting, ripping, and seeding, species seeded, and seeding rates). The procedures used to obtain these data are discussed in the following paragraphs.

14. Location of pitted and ripped areas. The WES used 1:5,000-scale color and 1:20,000-scale black-and-white aerial photography that had been acquired in 1974, together with information obtained from the Land Management Branch, DFAE, to identify the location and extent of pitted and ripped areas. The distinctive surface patterns of the pitted and ripped areas were identified by stereoscopic examination of overlapping photographs. The boundaries of the pitted and ripped areas were outlined on a U. S. Geological Survey (USGS) 1:50,000-scale map of Fort Carson (series V7710, 1973). Then, the WES map was compared with a map of pitted, seeded, and ripped areas prepared by the Land Management Branch, DFAE; and those areas pitted, seeded, or ripped

since 1974 were added to the WES map. Figure 6 presents the resulting map. (Table 2 lists the treated areas shown on the map.) The WES measured* the size of each treated area on the map and determined that 6179 acres had been pitted, 2078 acres had been pitted and seeded, and 83 acres had been ripped.

15. Vegetation reestablishment data. Vegetation reestablishment data were obtained from records maintained in the Land Management Branch, DFAE. Data abstracted from those records included: (a) date that pitting or ripping treatments were applied in each area shown in Figure 6, (b) acres pitted or ripped, (c) date seeded** (if area was seeded), (d) acres seeded, (e) species seeded, (f) seeding rate, and (g) whether the seeding was single species (seeds of one species are planted until supply is exhausted before another species is planted) or mixed species (a mixture of seeds of two or more species is planted until supply is exhausted). Table 2 summarizes the vegetation reestablishment data.

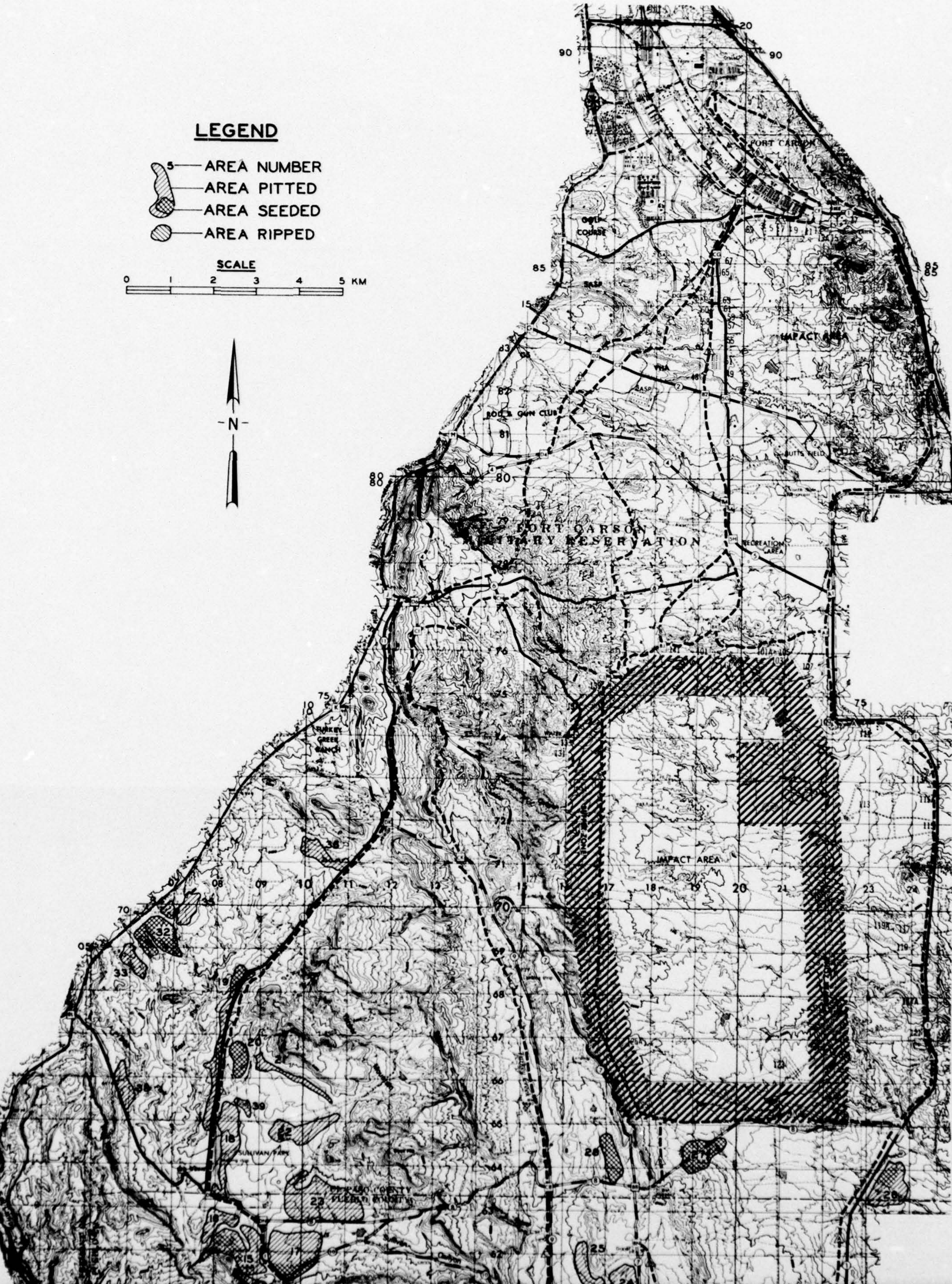
16. Terrain conditions in pitted and ripped areas. Soil types, average topographic elevations, and slope range in the pitted or ripped areas were determined. The USDA textural soil classifications for surface soils (0-4 in. in depth) at Fort Carson were obtained from SCS soils maps and interpretations of soils in the Fort Carson area as described in Report 1 of this series. Maximum and minimum elevations in an area were determined from a USGS 1:50,000-scale map of Fort Carson. Slope range for an area was determined from the USGS maps using the procedure described in Report 1. Table 3 outlines the data on terrain conditions in the pitted and ripped areas. Part III of this report presents detailed discussion of the pitted and ripped areas and the effectiveness of the procedure for establishing a vegetation cover.

---

* Size of the areas were determined by placing a Bruning Areagraph Chart (No. 4849) over an area depicted on the 1:50,000-scale map and counting the number of dots within the area boundary. The number of dots divided by 100 gives the area of the impoundment in square inches (at 1:50,000 scale). The area in square inches was multiplied by 399 (the number of acres per square inch at 1:50,000 scale) to obtain the area of each treated area in acres.

** All seeding was done by mechanical drill.

1


LEGEND
AREA NUMBER
AREA PITTED
AREA SEEDED
AREA RIPPED
SCALE
0 1 2 3 4 5 KM
N
FORT CARSON
IMPACT AREA
GOLF COURSE
ROD & GUN CLUB
BUTTS FIELD
FORT CARSON MILITARY RESERVATION
RECREATION AREA
IMPACT AREA

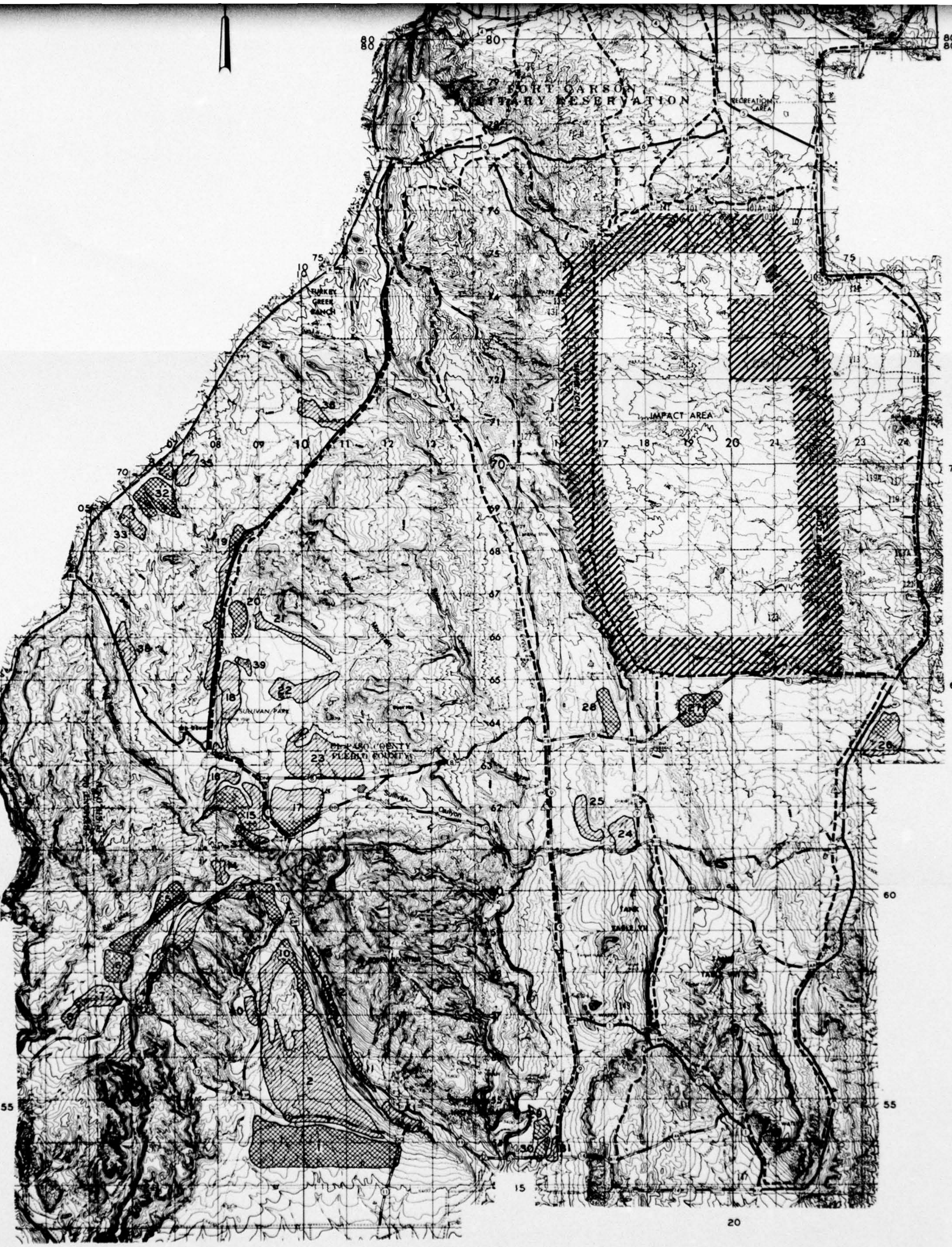


Figure 6. Areas pitted, ripped, and seeded from 1969 to 1976

2

Sediment Basins

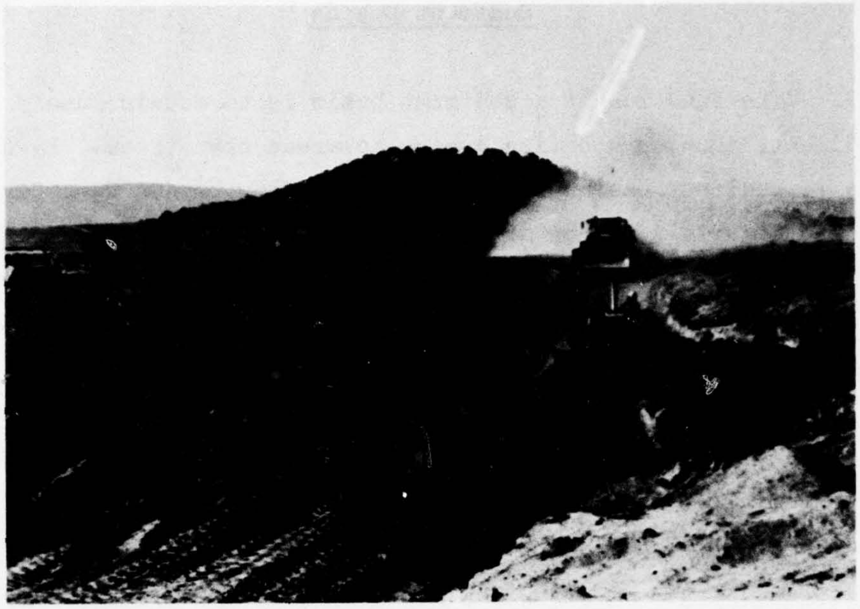
17. "The function of a sediment basin is to detain runoff and trap sediment, thus, preventing damage to areas downstream. By detaining runoff, sediment basins also reduce peak flow."[7] On Fort Carson, basins also provide a source of water for wildlife during the rainy season (April to September). Since 1968, Fort Carson land management personnel have constructed 51 sediment basins.

Construction techniques

18. Sediment basins on Fort Carson are constructed by excavating a pit in the center of a ravine, gully, or drainageway with Clark earthmovers and D-7 dozers. The material removed from the pit is used to build an earth-filled dam at the downstream edge of the pit (Figure 7a). The maximum height of the dam, the maximum storage capacity of the basin, and the size of the watershed area above the dam are regulated by Colorado State law. Land management personnel follow the SCS engineering standards for the construction of these earth-filled dams. The dams and basins are constructed to allow seepage and provide a maximum of surface area for evaporation so that most of the stored water is lost over the winter. This provides a maximum water storage capacity to hold runoff during the spring and summer rainy season (April to September). Suspended sediment carried in the runoff from the rains is deposited in the basins (Figure 7b). Figure 8 shows two typical sediment basins. Grass or riprap spillways are constructed to the side of each dam to prevent the runoff from unusually heavy rains from overtopping and cutting through the dam. After construction, dams are placed off limits to wheeled and tracked vehicles to prevent damage that could weaken the structure and possibly cause the dams to fail.

Location of existing sediment basins

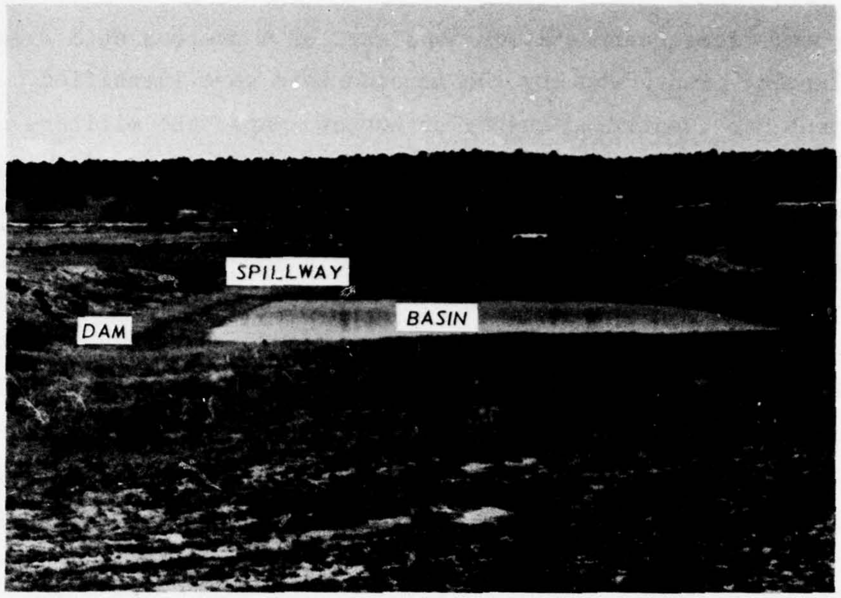
19. The locations of all impoundments (water-retaining structures) on Fort Carson were determined by photo interpretation of 1:20,000-scale black-and-white aerial photographs obtained in 1974 and from information contained on 1:25,000-scale orthopicto maps of



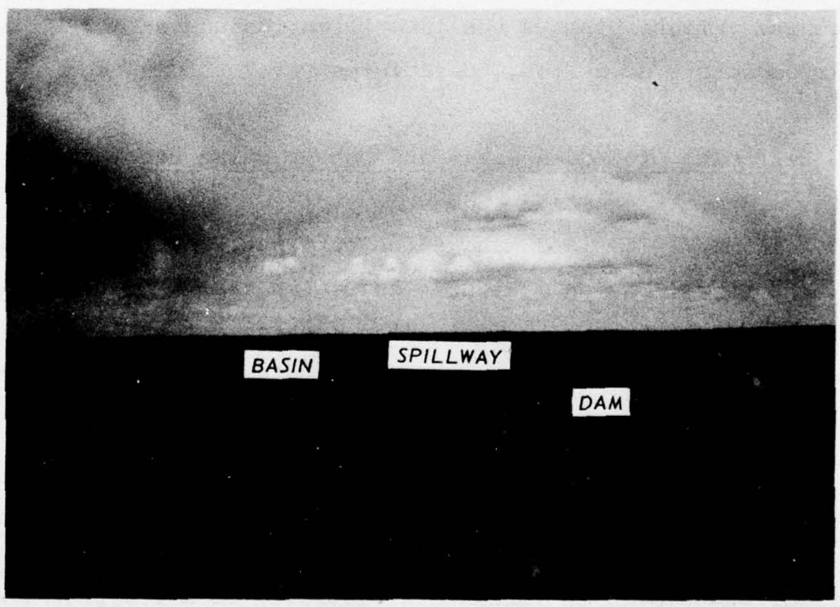
a. Construction of sediment dam and basin

b. Deposit of sediment in basin

Figure 7. Sediment dam and basin construction and results of placement in typical gully



a. Basins temporarily hold water in winter



b. Larger basins are built in large watersheds

Figure 8. Typical sediment dams and basins on Fort Carson

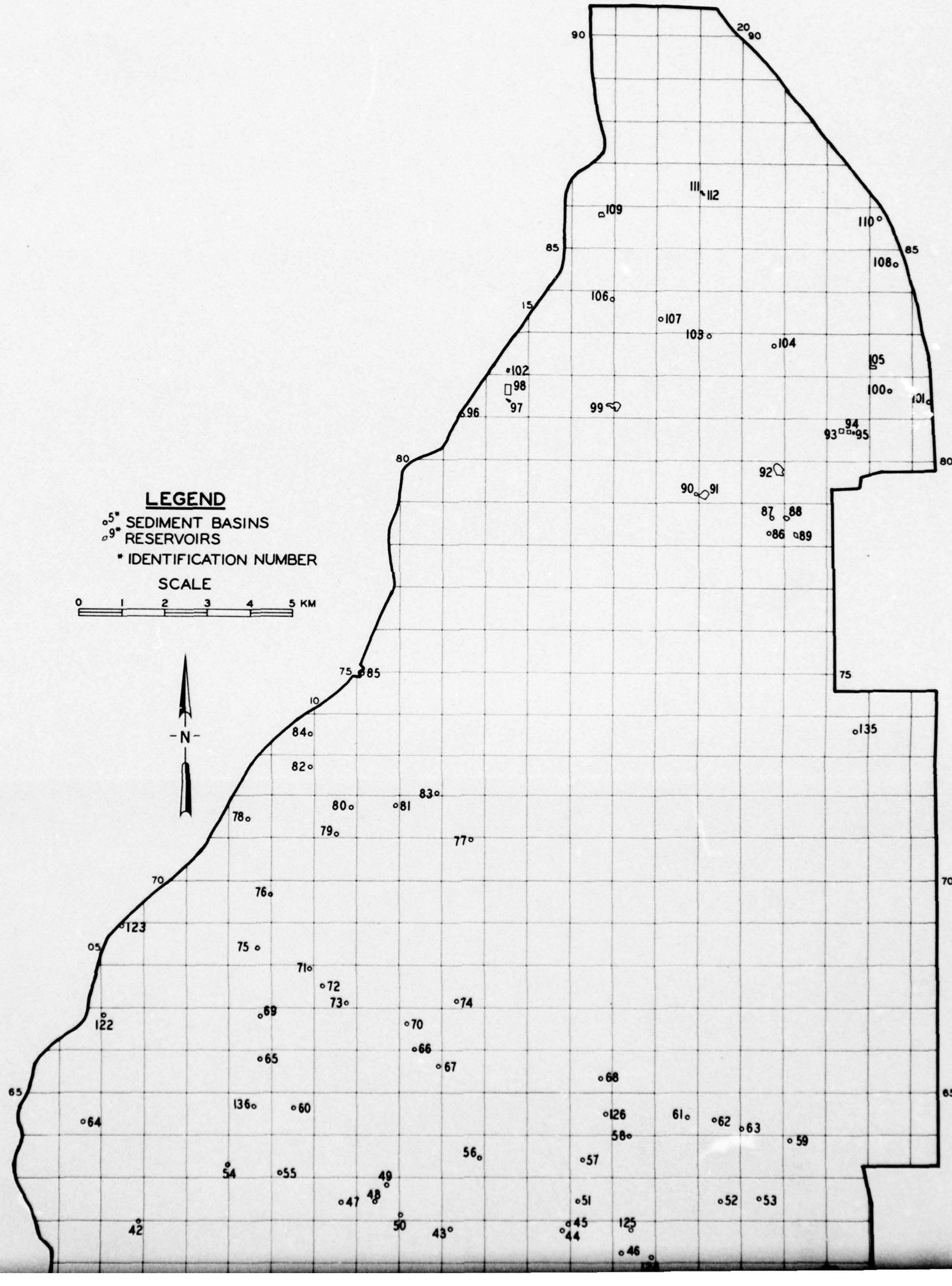
Fort Carson. The interpretation consisted of a stereoscopic examination of overlapping prints whereby the impoundments were identified. As each impoundment was identified on the orthopicto maps, the military grid coordinates and approximate water surface area* were recorded and the locations numbered. The locations of impoundments visible on the aerial photography, but not shown on the orthopicto maps, were recorded, but water surface areas were not determined for those impoundments since the impoundments were dry at the time of photography and the aerial extent of the basin could not be determined. The map showing the location of 146 impoundments that were identified using this procedure was inspected by Fort Carson land management personnel who determined that 17 impoundments were "reservoirs" (impoundments with a permanent water surface) and 129 were "sediment basins" (impoundments with a temporary water surface). Names of reservoirs were obtained from the orthopicto maps. Table 4 presents the identification number, location (military grid coordinates), approximate water surface area, and classification of the impoundments. Figure 9 shows the identification number and location of the impoundments on a 1:50,000-scale map of Fort Carson.

Reshaping of Eroded Areas and Constructing Debris Dams

20. In May 1976, land management personnel initiated a new project to control erosion on those landscapes that had undergone significant soil losses. The project consisted of first reshaping the eroded terrain surface, constructing numerous small debris dams to reduce the velocity of surface runoff and to catch (or trap) the sediment being transported by surface runoff, and establishing a protective vegetation cover. The site chosen for the initial

---

* Water surface areas were determined by placing a Bruning Areagraph Chart (No. 4849) over an impoundment depicted on a 1:25,000-scale orthopicto map and counting the number of dots within the impoundment boundary. The number of dots divided by 100 gives the area of the impoundment in square inches (at 1:25,000 scale). The area in square inches was multiplied by 403226 (the number of square metres per square inch at 1:25,000 scale) to obtain the area of the basin in square metres.


LEGEND
5* SEDIMENT BASINS
9* RESERVOIRS
* IDENTIFICATION NUMBER
SCALE
0 1 2 3 4 5 KM
N

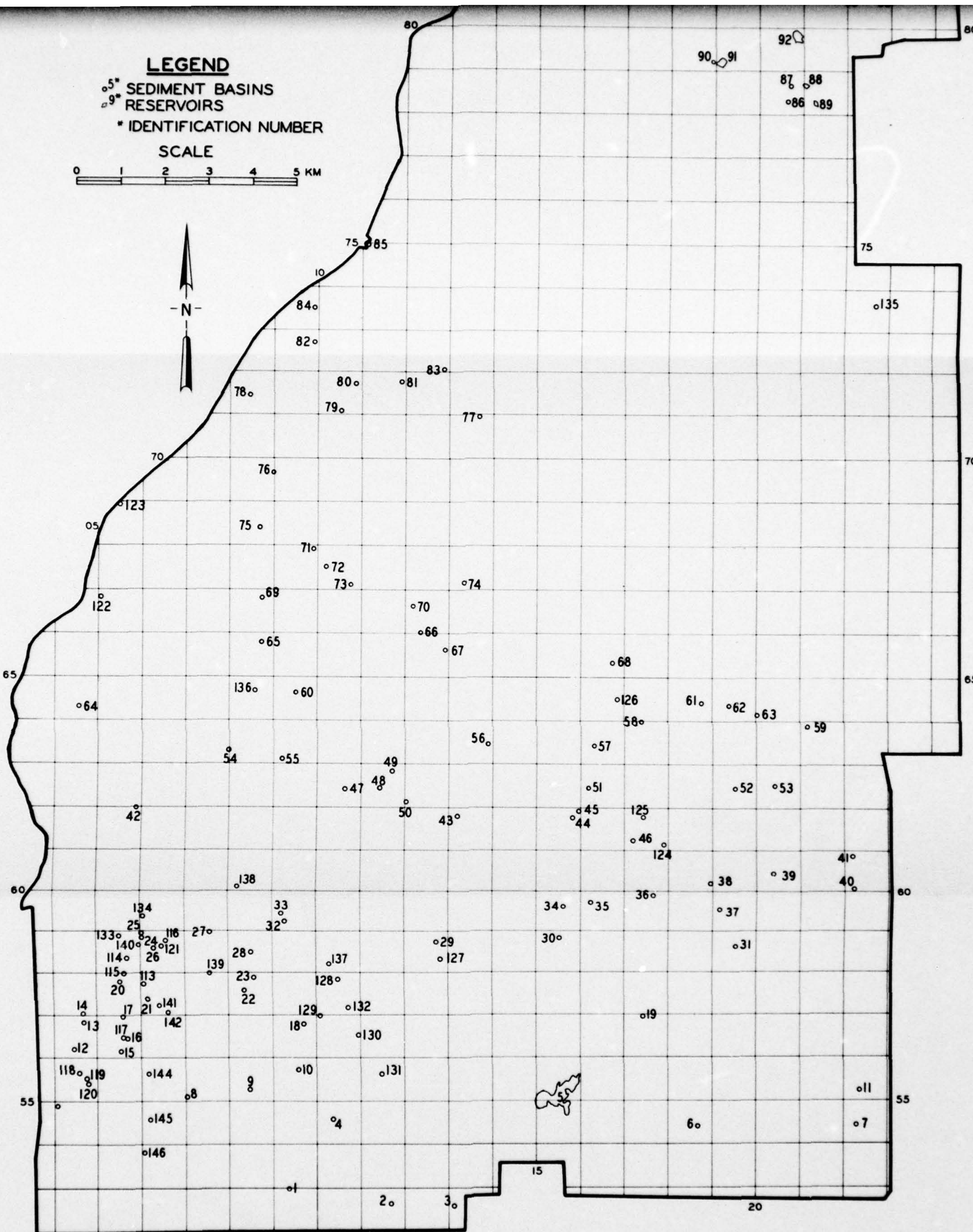


Figure 9. Location of impoundments on Fort Carson, 1:50,000-scale map

demonstration of this erosion control method was near Stone City, bordering on Booth Gulch (Figure 10). The method required three steps as discussed below.

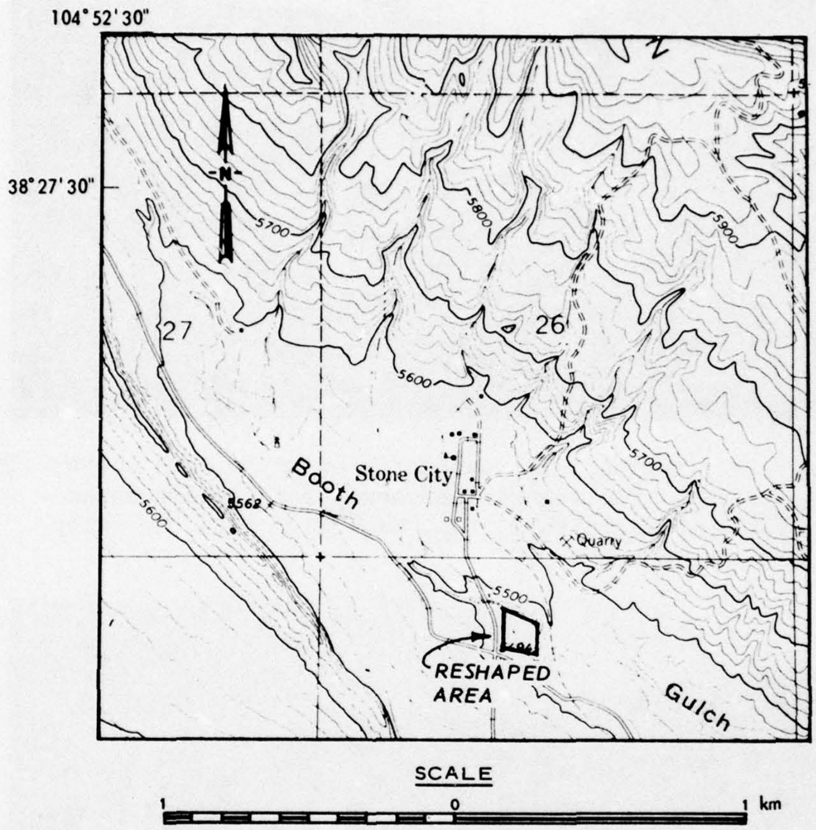


Figure 10. Location of area that was reshaped and used to construct debris dams or traps (military coordinates 12355495)

Reshaping of
eroded terrain surface

21. The terrain surface in the project area had undergone extensive erosion with high soil losses as a result of rainfall on the unprotected soil surface. This soil erosion had left numerous steep-sided gullies in the terrain surface (Figure 11) that drained into Booth Gulch (a large arroyo, Figure 12). Since the sides of the gullies were too steep and gully erosion too rapid for stabilizing

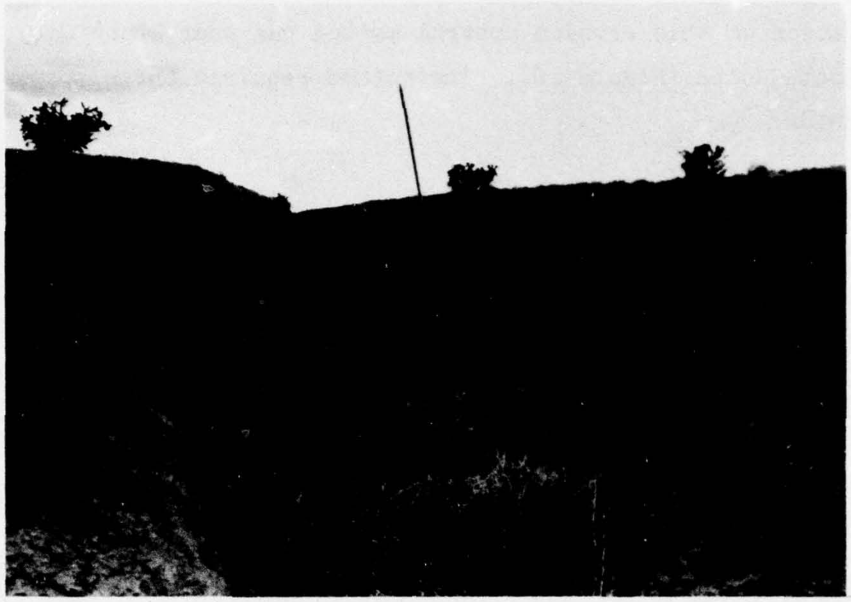


Figure 11. Typical pretreatment view of terrain surface in project area. The vegetation consists of dead Russian thistle (Salsola kali) that was blown into the gully

Figure 12. Booth Gulch adjacent to reshaped site

vegetation to become established, land management personnel reshaped the gullies to reduce and smooth the slopes and compacted the soil to prepare a firm seedbed for seeding grasses. The reshaping and compaction of the new surface were accomplished with D-8 bulldozers and sheepsfoot rollers.

Construction of debris dams

22. Once the surface had been prepared, 12 debris dams were built in the drainageways to trap the sediment transported by surface runoff. A WES field team surveyed the project area in June 1976 to establish the locations of the dams and the depths of the drainageways immediately upstream from the dams. Figure 13 presents a panoramic

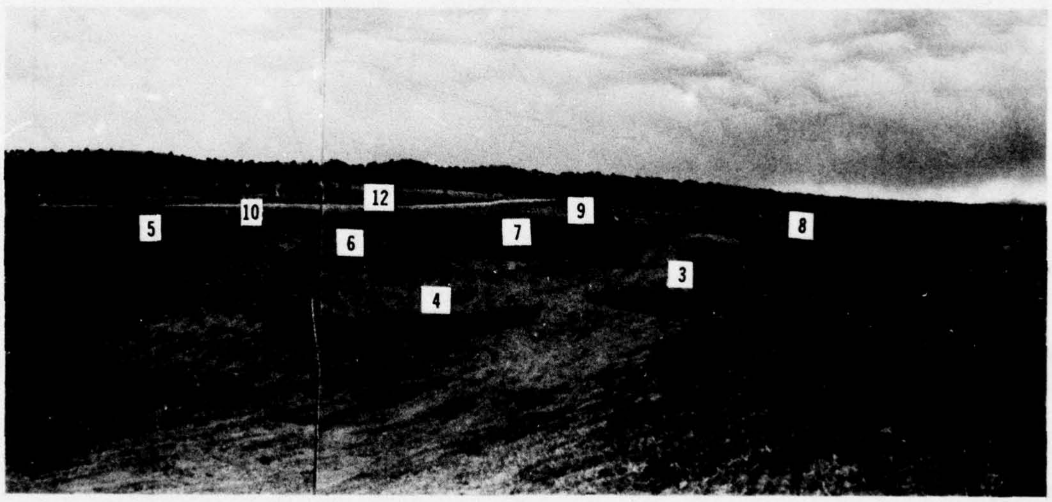


Figure 13. Panoramic view of reshaped area showing sediment structures 5, 10, 6, 12, 4, 7, 9, 3, and 8

view of the reshaped area showing nine of the sediment structures. Figure 14 shows the locations of the surveyed dams.

23. The debris dams were built with salvaged railroad crossties, rocks, dead juniper trees, and brush. These locally available materials were held in place with fencing (barbed wire and metal posts). Figure 15 contains a detailed view of structure 1, and Figure 16 of structures 7 and 8. Table 5 lists the data pertaining to the heights of the debris dams.

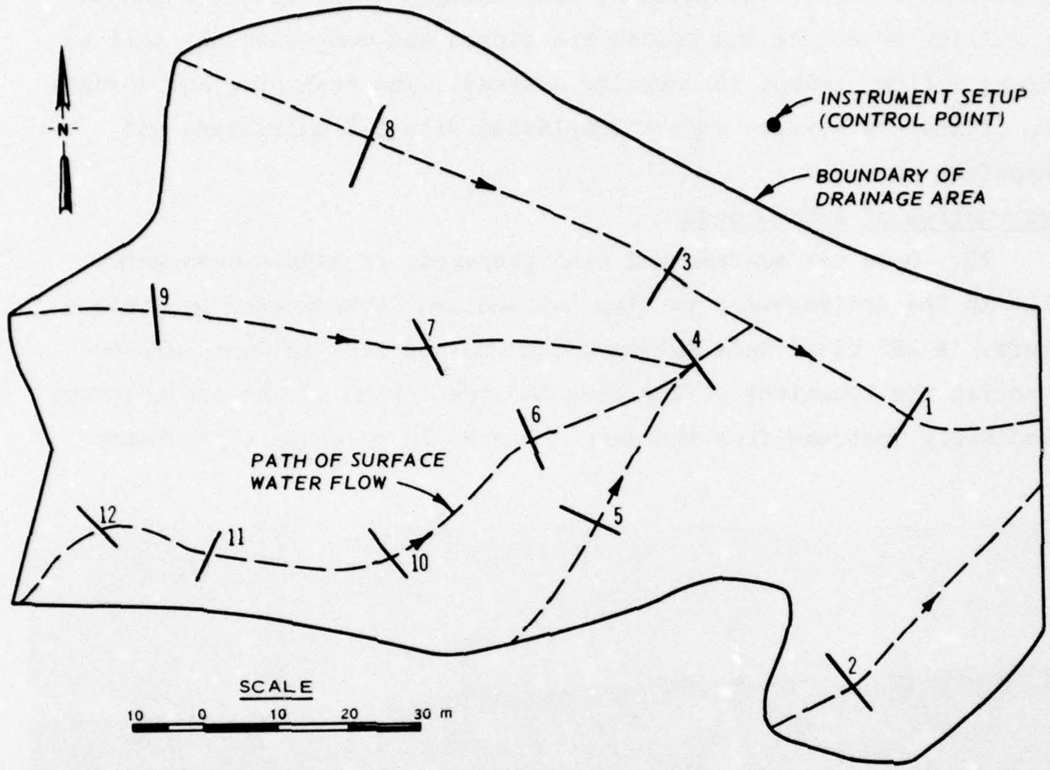
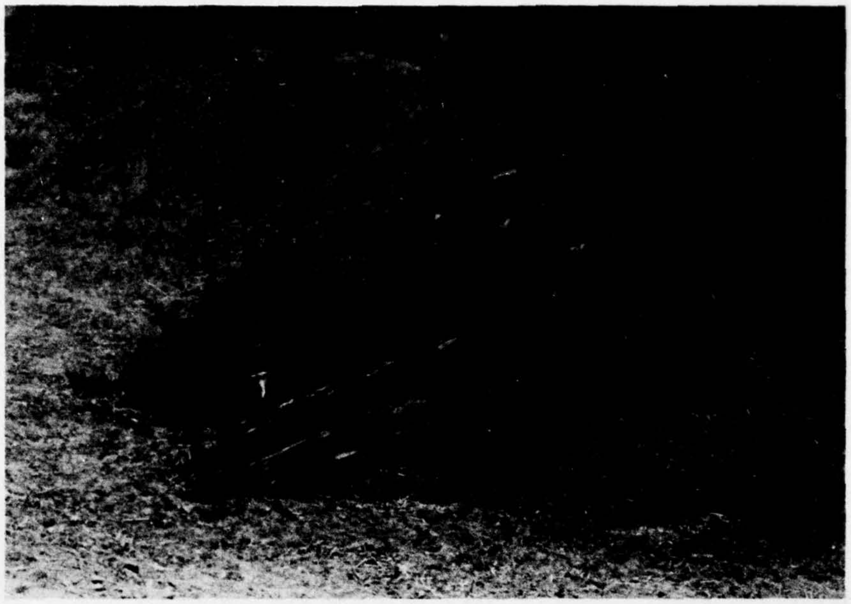


Figure 14. Sediment control structures (debris dams)

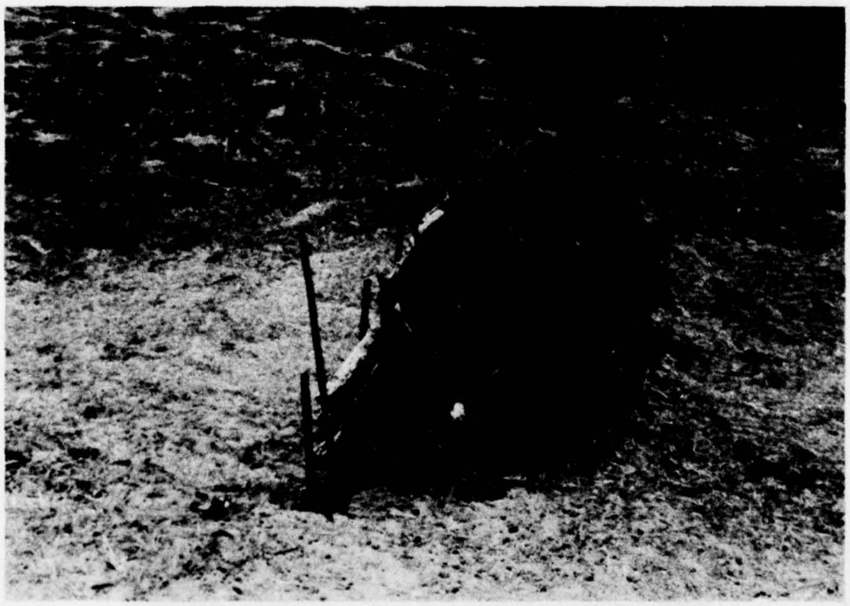
Mulching and seeding

24. After construction of the debris dams, a hay mulch was hand-emplaced on the prepared soil surface of the gulches. The mulch was pinned to the soil by use of a farm tractor and notched-bladed disk, the results of which are shown in Figure 17. The hay mulch was used to slow the surface runoff and thereby minimize the erosion of the new surface until the planted grasses had sufficient time to become established. The mulched surface was then seeded by hand (May 1976) with the following two types of grasses:

Grass Type (Common Name)	Seeding Rate, lb/acre
Western wheatgrass	5
Blue grama	3



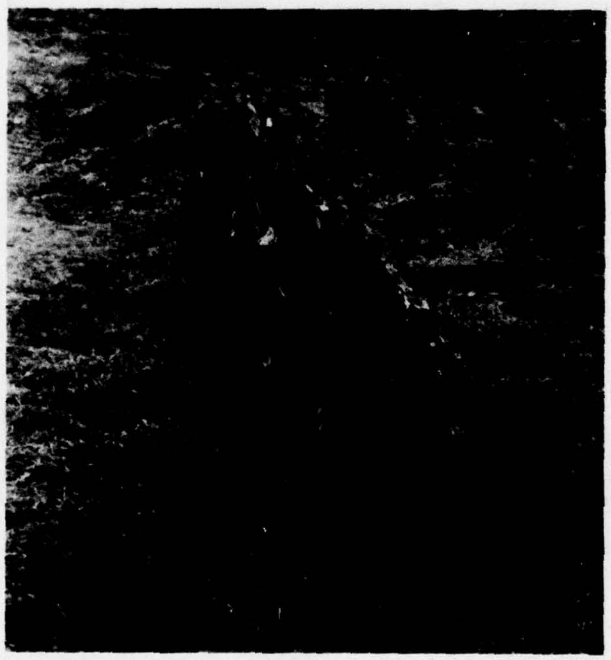
a. Downstream side of debris dam



b. Upstream side of debris dam

Figure 15. Debris dam 1 constructed of salvaged railroad crossties, rocks, dead juniper trees, and brush held in place by barbed wire fencing and metal posts

a. Dam 7



b. Dam 8

Figure 16. Debris dams 7 and 8

Figure 17. Hay mulched surface after use of disk

Diversions and Floodwater Spreaders

25. Fort Carson land management personnel constructed several diversions and floodwater spreaders during FY 77. The diversions, which were bulldozed with D-7 tractors, lead to either a sediment basin for storage or a floodwater spreader where the runoff is spread over an area with enough existing vegetation to retain and hold the runnoff until it infiltrates the soil.

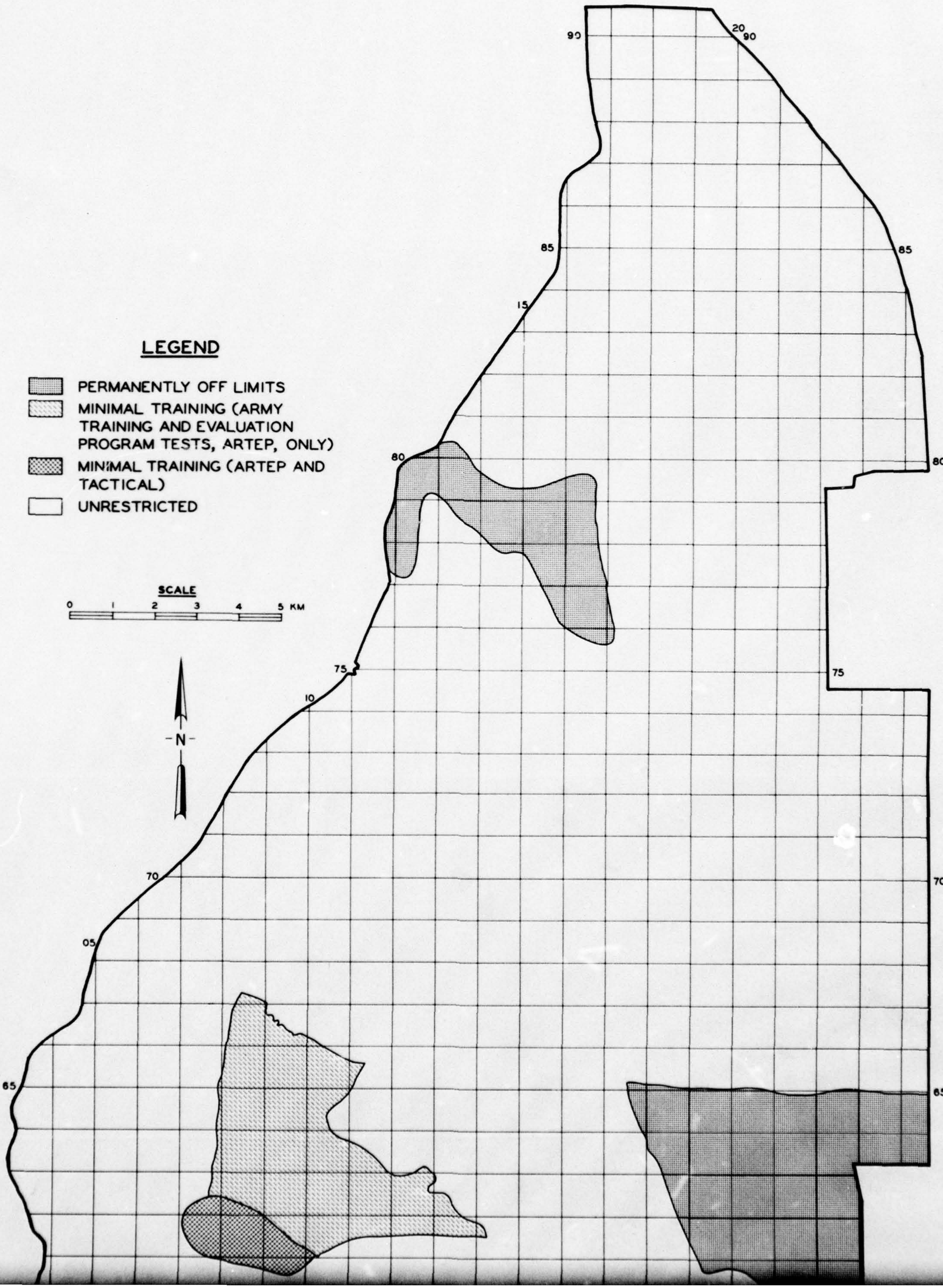
Establishment of Restricted Use Areas

26. Land management personnel indicate that the most serious land management problem results from mechanized training maneuvers in the limited areas available for this purpose. While the impact of training may vary (in degree of damage) from one area to another, the primary problems encountered with this training are: (a) loss of plant cover and attendant increase in erosion, (b) difficulty of

establishing vegetative cover even under nonuse conditions, (c) the recognized need to perform the training mission, and (d) the need for a schedule to rotate the high-use training areas to provide a period for damaged vegetation to recover while also ensuring that sufficient areas were available for troop training.

27. Several areas of Fort Carson do not have sufficient vegetative cover to prevent severe soil erosion. Any maneuvers in these areas damage the vegetation and increase the soil erosion. These areas have been designated permanently "off limits" until sufficient vegetative cover is established. Other areas of Fort Carson have sufficient vegetation to prevent severe soil erosion, but any damage to the vegetation would lead to significant soil erosion. These areas are designated areas of "minimal training" and are used for training during the period September to April when the grass is dormant and less susceptible to damage.

28. The WES obtained from the Land Management Branch, DFAE, a 1:50,000-scale map of Fort Carson showing the restricted areas that had been established and determined the total area under each restriction. At the present time (1976), 13,300 acres of Fort Carson (≈10% of the area of the installation) have been designated as permanently "off limits" and 13,150 acres have been designated areas of "minimal training" (Figure 18).


LEGEND
PERMANENTLY OFF LIMITS
MINIMAL TRAINING (ARMY TRAINING AND EVALUATION PROGRAM TESTS, ARTEP, ONLY)
MINIMAL TRAINING (ARTEP AND TACTICAL)
UNRESTRICTED
SCALE
0 1 2 3 4 5 KM
N
90
20
85
15
80
75
10
70
05
65

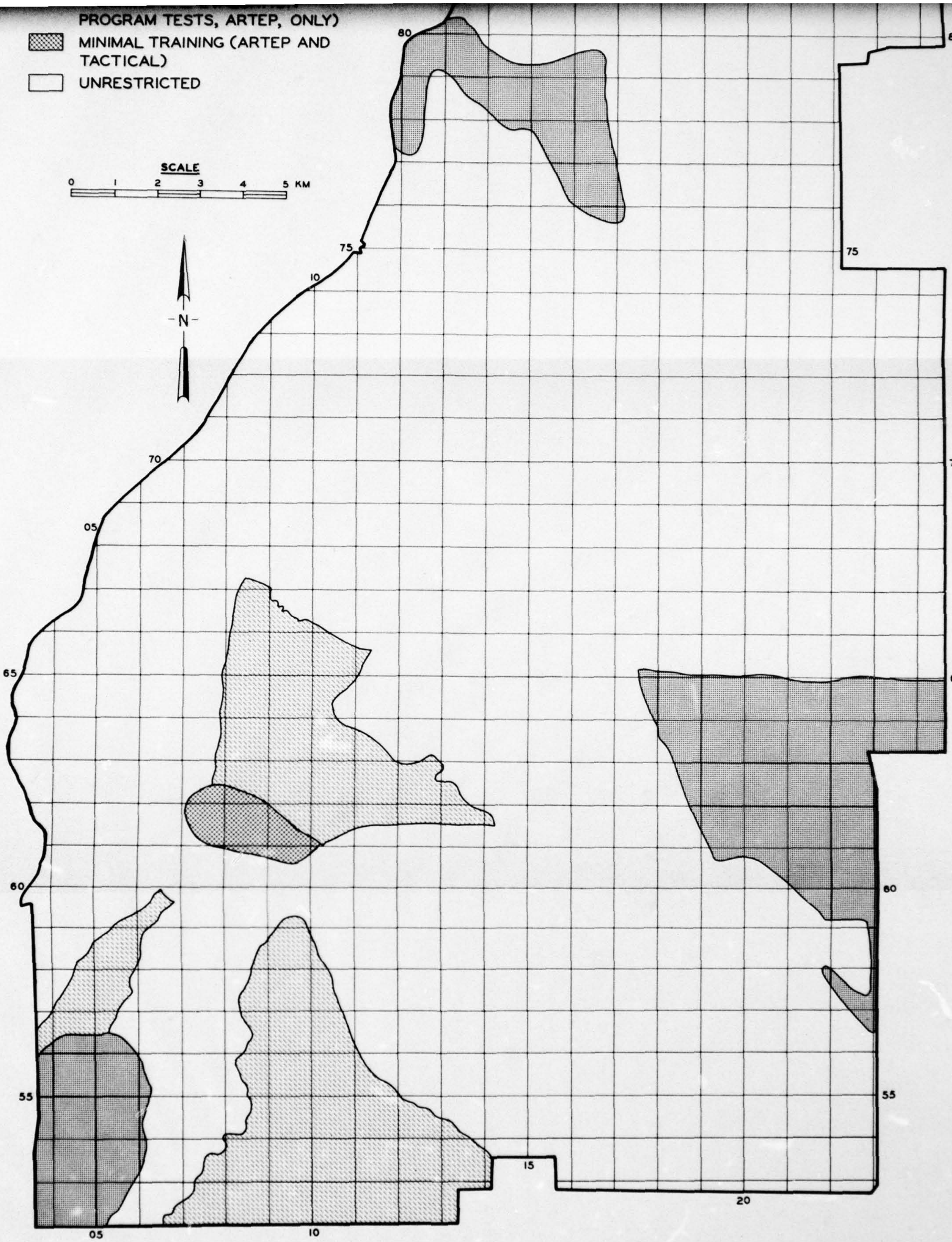


Figure 18. Fort Carson map, 1:50,000 scale, showing areas designated "permanently off-limits" and areas designated "minimal training"

PART III: EVALUATION OF FORT CARSON RESTORATION METHODS

Introduction

29. Since the Land Management Branch, DFAE, was concerned about the effectiveness of their vegetation restoration methods, quantitative field assessments of the vegetation in the pitted, pitted and seeded, and ripped areas at Fort Carson were made by a WES team during the period July-August 1977. Data on in situ species densities, coverages, and heights were obtained at sites inside 36 of the 41 areas* (Figure 6) where restoration work had been conducted (hereafter called treated areas), and at sites outside the 36 treated areas where there had been no restoration work (hereafter called untreated areas). The following two sections discuss the evaluation of the vegetation and mechanical restoration methods, respectively.

Evaluation of the Vegetation Restoration Methods

30. The sampling techniques, analysis of the collected vegetation data, and evaluations of the results are presented in the following paragraphs.

Field sampling

31. A 1- by 1-m-square sample area or quadrat was the standard size area for field characterization of the vegetation within the treated and untreated areas. The WES used the quadrat method as a basis for vegetation sampling in this study, since this is an established method commonly used by rangeland management personnel for characterization of grass-type vegetation.

32. Sampling apparatus. The sampling apparatus (similar to that used by Smartt, Meacock, and Lambert[8]) consisted of a frame constructed of 2-in. (5.1 cm) aluminum angles joined together to give a square with inside length dimensions of 1 m. A wire was laced through

---

* Treated areas 11, 12, 13, 36, and 41 were omitted from the sampling program.

the opposite sides to give a set of 10- by 10-cm^2 subunits, dividing the inside area of the quadrat into 100 equally sized (0.01-m^2) subsquares (Figure 19).

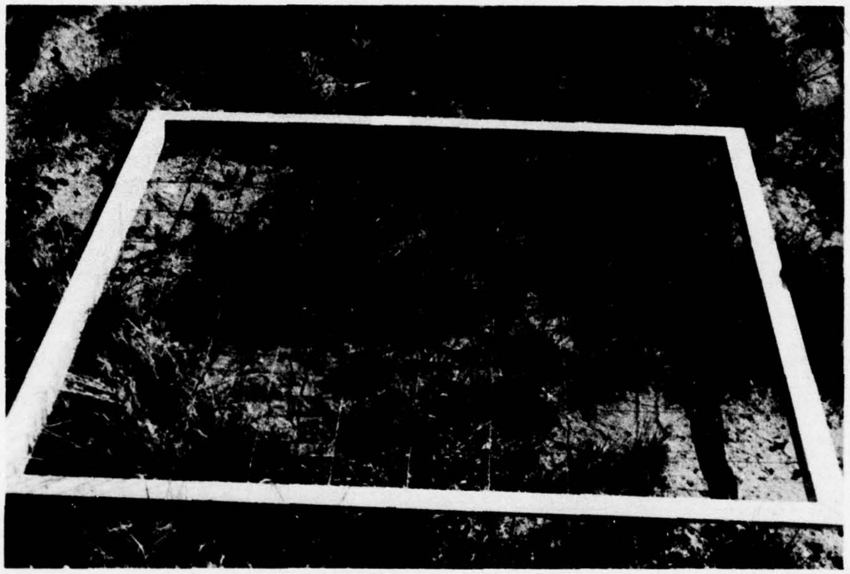


Figure 19. One-metre-square frame used for sampling vegetation cover and density in the treated areas

33. <u>Selection of sampling sites in treated areas.</u> To minimize any in-the-field bias in the selection of sampling sites in the 36 treated areas, a random site selection procedure was followed.[9-11] Prior to making the field assessments, the delineated boundary of each treated area on the 1:50,000-scale Fort Carson map (see paragraph 14) was traced on graph paper having 10 divisions to the inch and enclosed by a set of lines to form a rectangle around the area. Each intersection of the division lines of the graph paper within the rectangle was assigned a number by counting from left to right and top to bottom (Figure 20). A table of random numbers[12] was then used to select a random number that represented an intersection number within the rectangle. If the number selected represented an intersection number within the rectangle but outside the boundary of the treated area, it

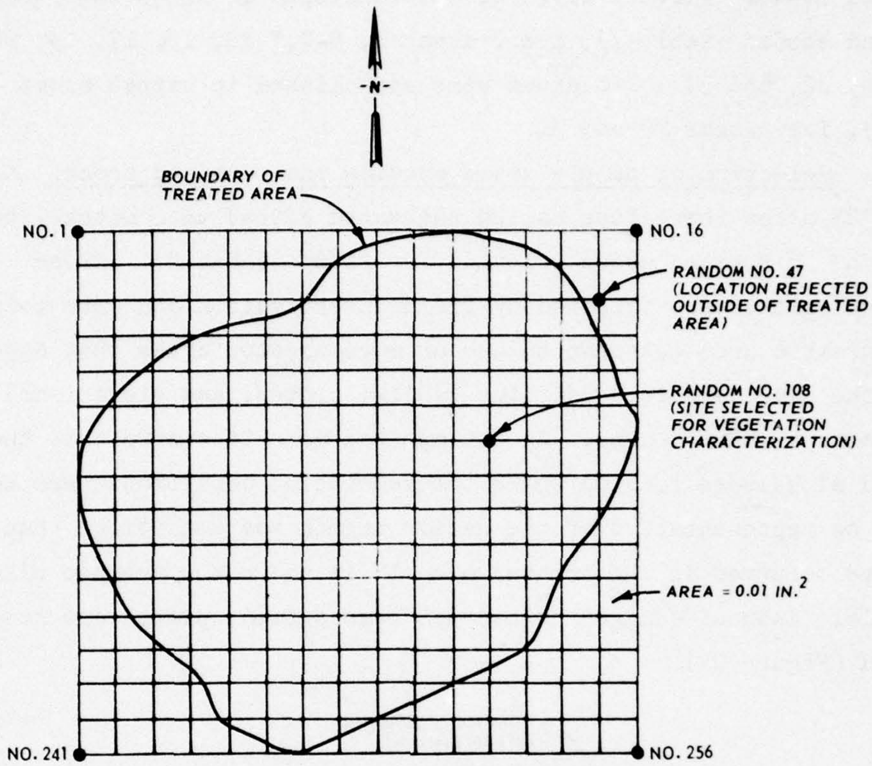


Figure 20. Selection of random vegetation sample site locations in treated areas

was rejected as a sampling site. If the number selected represented an intersection number within the boundary of the treated area, that intersection was accepted as the location of a sampling site. In the field, the WES team located the preselected sampling site in the treated area and determined whether the terrain (soils, slopes, and elevations) and vegetation in the selected site were representative of the terrain and vegetation in the entire treated area. In any instances where the preselected site occurred in gullies, washouts, or on terrain recently disturbed by human activities (bulldozed area, vehicle maneuver area, or road), an alternate site was selected at random using the selection technique described previously.

34. Forty-four sampling sites were established in the 36 treated areas (see paragraph 29). Twenty-seven sites were established in pitted areas (Table 6), i.e., areas 2-4, 7-10, 14-19, 21-26, 31,

33-35, and 37-40. Fifteen sites were established in areas that were pitted and seeded (Table 7), i.e., areas 1, 5-7,* 10, 15, 17, 19, 20, 22, 26-28, 32, and 37. Two sites were established in ripped areas (Table 8), i.e. areas 29 and 30.

35. Selection of sample sites outside the restored areas. A total of 25 sites (hereafter called untreated sites) were established outside the 36 treated areas selected for study (Table 9). These "untreated" sites were selected by field investigation and were located in an untreated area adjacent to one or more treated areas that appeared to have the same terrain conditions (soils, slopes, and elevations) as the respective treated area. An attempt was made to ensure that the untreated sites were located where the vegetation conditions were assumed to be representative of the native vegetation conditions that would have occurred in the treated area if it had not undergone military vehicle induced damage and had not been pitted, pitted and seeded, or ripped (Figure 21).

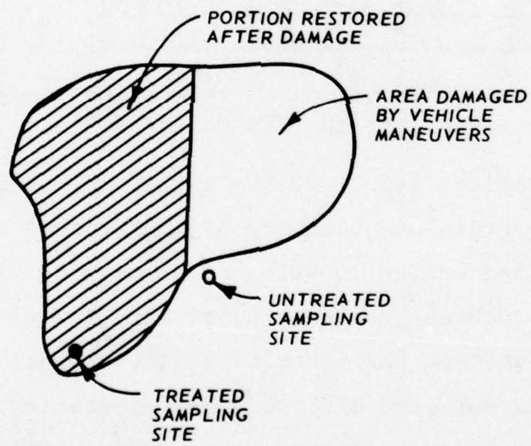


Figure 21. A sketch showing the location of treated and untreated sample sites

---

* In those pitted areas where only part of the total pitted area was seeded (areas 7, 10, 15, 17, 19, 22, 26), one sample site was established in the pitted part, and one sample site in the pitted and seeded part.

36. Vegetation characterization. Once a sampling site was selected, a 40-m-long line was laid out in a westernly direction from the point. Three quadrat sites were selected along the 40-m line; the positions were at the beginning, middle, and end of the line. The first quadrat (east end of the line) was laid randomly to the north or south of the line as determined by a flip of a coin. Each of the two successive quadrats was then placed on the opposite side of the line from the preceding one. For each selected quadrat site, the following information about the vegetation within the frame boundaries was determined in the field and recorded on a data form (Figure 22).

a. Species present.

b. Number of plants of each species present in the entire 1 m^2 for nongrass species, or the number of culms in a 0.01-m^2 tuft or sod in the case of grass species.

c. Percent cover.

d. Maximum height (cm) of vegetative or reproductive structures of each species.

e. Average height (cm) of the vegetative structures of each species when viewed horizontally with respect to the ground.

f. Presence (yes) or absence (no) of any existing reproductive structures (flowers or fruits) for each species.

Additionally, each quadrat was documented by sketching the placement and areal extent of ground covered (when viewed from above) by each species on a scale grid drawing (Figure 22). Photographs of each quadrat were also obtained.

37. Number of quadrat samples. Three 1-m^2 quadrat samples were determined to be adequate to characterize the plant species in each site. Data were selected from the first nine sampling sites for analyses by the species area curve method described in References 13-15. This method uses the relationship between the increase in number of new species observed and the accumulated number of quadrats sampled. An adequate number of quadrats is sampled if the addition of a quadrat produces a 10% or less increase in the number of new species sampled.

VEGETATION DATA FORM

SPECIES	NUMBER STEMS dm^2 OR m^2	PERCENT COVER	MAXIMUM HEIGHT cm	AVERAGE HEIGHT cm	REPRODUCTIVE STRUCTURES YES OR NO
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					
K					
L					
M					
N					
O					
P					
Q					
R					
S					
T					
U					
V					
W					
X					
Y					
Z					

LOCATION ____________________

MILITARY GRID COORDINATES ____________________

DATE ____________________

PHOTO NO. ____________________

QUADRANT NO. ____________________

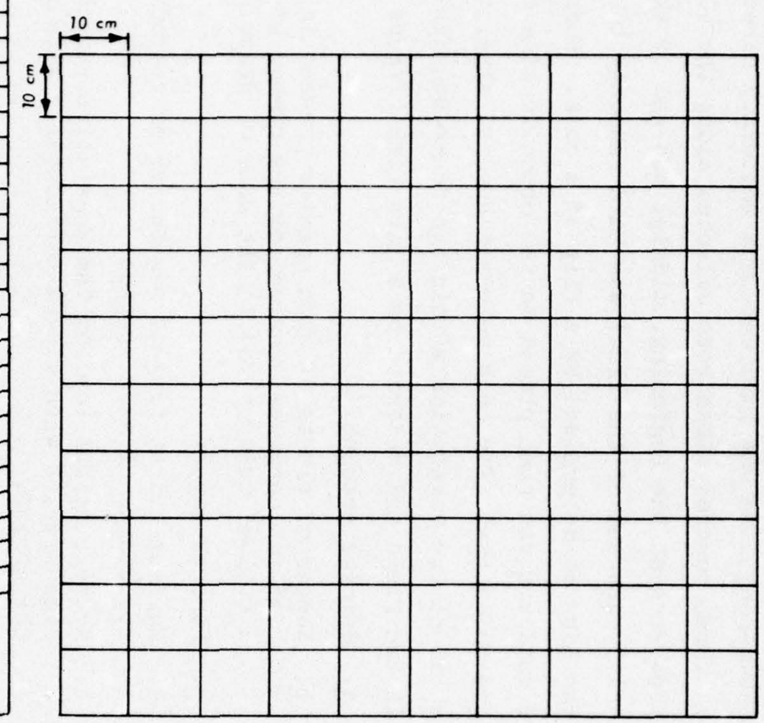


Figure 22. Example of vegetation data form used to record information in the field

Analysis of vegetation data

38. The vegetation data collected in the treated and untreated sampling sites were analyzed to obtain the following:

a. Frequency. The frequency of each species in a site was determined by counting the number of 0.01-m^2 subunits in the three quadrats in which each species occurred and dividing that number by three. Frequency was an indication of the distribution of that species within the sample site.

b. Density. The density (stems/m^2) of each nongrass species in a site was determined by summing the density of the species in the quadrats and dividing that number by three. The density of each grass species in a site was determined by multiplying the number of culms in a 0.01-m^2 tuft or sod times the percent cover of that species in the site.

c. Percent cover. The percent cover of each plant species in the sample site was determined by counting the number of 0.01-m^2 subunits in the three quadrats in which the species covered half or more of the subunit based on the field sketch. The percentage obtained was divided by three to obtain the percent cover of that species in the site.

d. Maximum height. The maximum height of each species in a site was the maximum height recorded for a reproductive or vegetative structure of that species in the three quadrats.

e. Average height. The average height of each species in a site was determined by summing the average height of that species in the three quadrats and dividing that number by three.

f. Flowers or fruits present. The presence of flowers or fruits on each species in a site was determined to be (yes) if there were flowers or fruits on any individual of that species in any of the three quadrats and (no) if there were no flowers or fruit on any individual of that species.

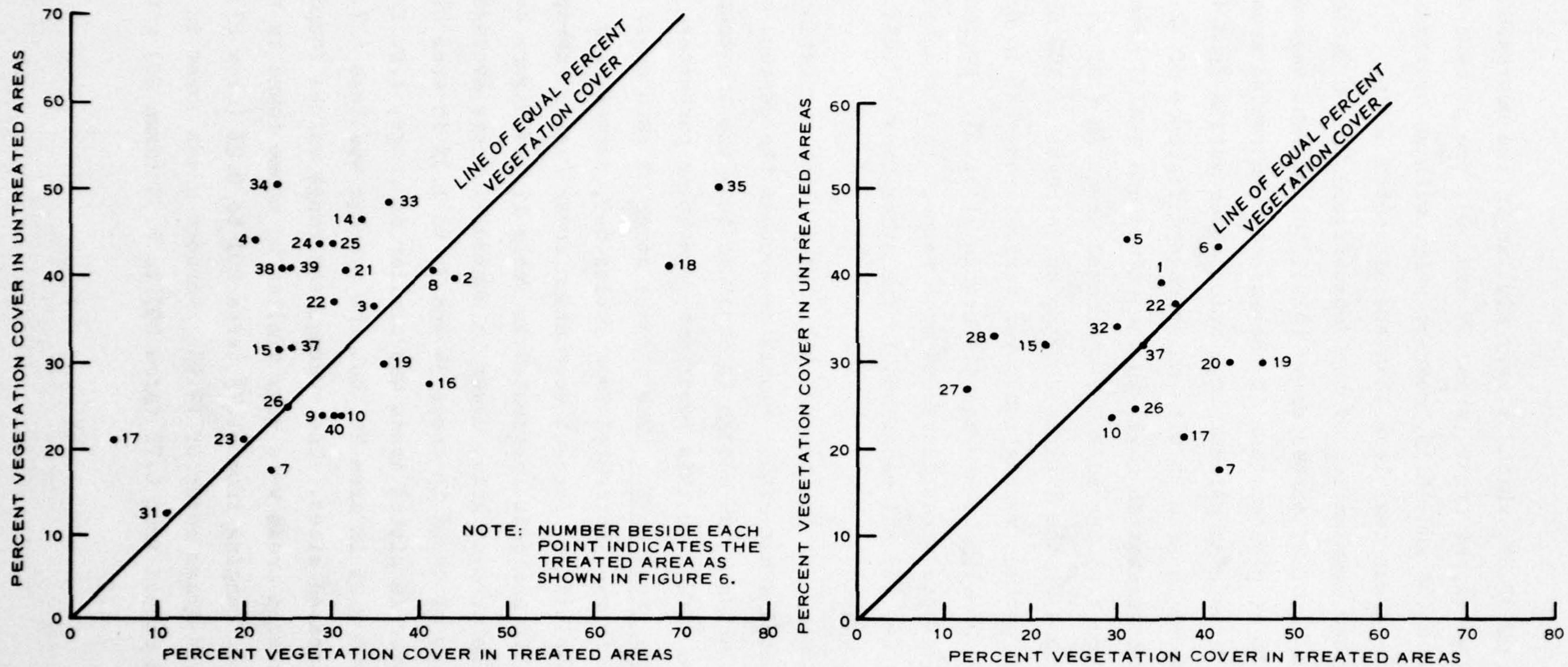
39. The results of the above analysis for each pitted, pitted and seeded, ripped, and untreated site is summarized in Tables 6-9, respectively. Table 10 presents a list of scientific names of the plant species found in the sample sites.

40. The summarized data were analyzed by comparing the percent vegetation cover, percent grass cover, vegetation density, and grass

density in the treated areas with those found in the untreated areas. The analysis of the data contained in Tables 6-9 is described in the following paragraphs.

41. Percent vegetation cover. The percent vegetation cover was the sum of the percent cover of each plant species in a site. In Table 11, the percent vegetation cover was tabulated according to the area number and type of area (untreated, pitted, pitted and seeded, and ripped). The difference in percent vegetation cover between untreated and pitted areas was calculated by subtracting the value for the percent vegetation cover in the untreated area (Table 11, column b) from the value for the percent vegetation cover in the pitted area (Table 11, column c). Positive values indicated more vegetation cover in the pitted with respect to the untreated areas, and negative values indicated less vegetation cover in the pitted areas with respect to the untreated areas. Similarly, the difference values were calculated for vegetation cover in the pitted and seeded areas (Table 11, column f) and the ripped areas (Table 11, column h). Next, the tabulated data on the pitted and the pitted and seeded areas were plotted to identify any trends in the data in the following manner. The values for percent vegetation cover for each pitted and each pitted and seeded area were compared with the adjacent untreated area by plotting percent vegetation cover in the untreated areas versus percent vegetation cover in the adjacent pitted areas (Figure 23a) and versus percent vegetation cover in the adjacent pitted and seeded areas (Figure 23b). Since there were only two ripped areas (areas 29 and 30), plots were not constructed for these two areas.

42. The tabular and graphic analysis of percent vegetation cover (Table 11 and Figure 23, respectively) indicate that the average percent vegetation cover in untreated areas was 34.1% with a range of 12.5% (areas 30 and 31) to 50.7% (areas 34 and 35). In the pitted areas, the spread was greater, ranging from 5.1% (area 17) to 74.3% (area 35), and the average slightly less, i.e. 31.7%. Percent vegetation cover in pitted and seeded areas ranged from 12.3% (area 27) to 46.0% (area 19) with an average percent vegetation cover for all pitted



a. Pitted areas

b. Pitted and seeded areas

Figure 23. Comparison between percent vegetation cover in untreated and treated areas

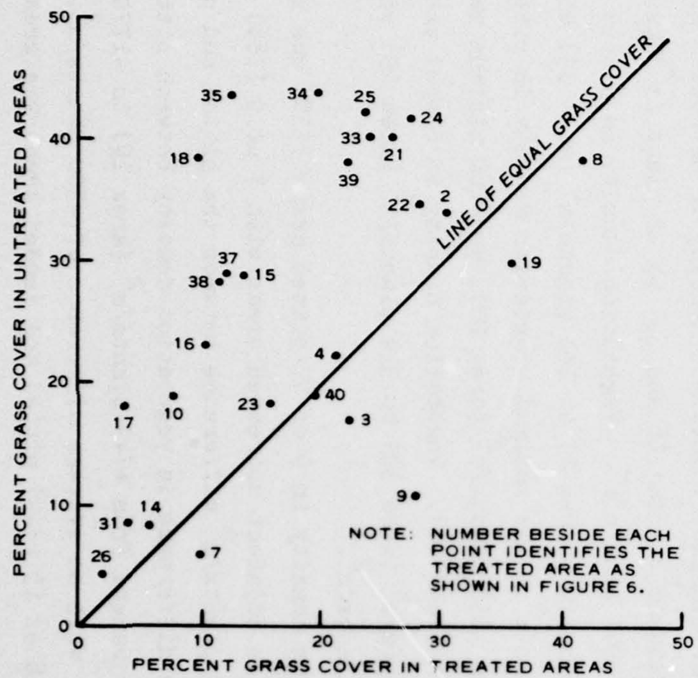
and seeded areas of 32.2%, which is very similar to the untreated area. However, in the two ripped areas (areas 29 and 30), the percent vegetation cover was 25.8% and 18.1%, respectively, with an average of 22.0%, which was a great deal less than the untreated areas.

43. A further examination of the data (Figure 23 and Table 11) indicates that in 11 of 27 pitted areas (41%), the percent vegetation cover was equal to or greater than in the adjacent untreated areas. Overall, the difference in percent vegetation cover varied from +27.2% in area 18 to -24.4% in area 34 with an average difference of -2.7%.

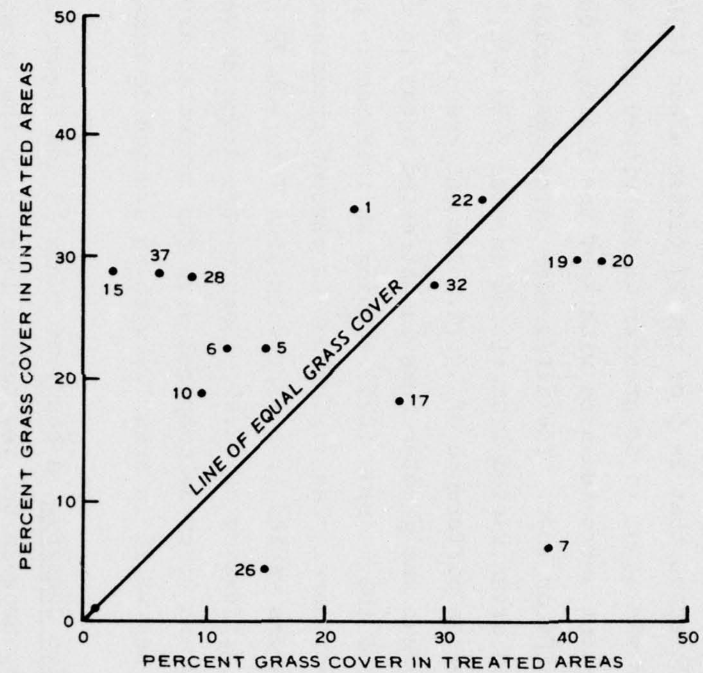
44. Percent vegetation cover in the pitted and seeded areas was greater than or equal to the adjacent untreated areas in 7 of 15 areas sampled (46%) with 4 of the 7 sites showing an increase of 10% or more. The difference in percent vegetation cover varied from +24% in area 7 to -17.8% in area 28 with an average difference of +1.0%. Percent vegetation cover in ripped areas increased with respect to the untreated area in one case (+5.6%) but decreased in the other case (-7.0%). The average decrease was -0.7%.

45. In summary, it is apparent that the percent vegetation cover in the treated areas either equals or exceeds the percent cover in the untreated areas often enough to conclude that the treatments are having a positive effect on this important vegetation parameter.

46. Percent grass cover. The percent cover of each grass species in the site was abstracted from Tables 6-9, summed, and tabulated as described for percent vegetation cover (see paragraph 41). The results of this analysis (presented in Table 12 and Figure 24) indicated that the percent grass cover in untreated areas averaged 25.8% with a range of 44.0% in areas 34 and 35 to 1.2% in area 27. Percent grass cover in pitted areas was similar in range, i.e. from 41.4% in area 8 to 2.2% in area 26, but the average was less (17.9%) than for the untreated sites. The average and range values found in the pitted and seeded areas were very similar to those found in the pitted areas, i.e. ranging from 41.7% (area 20) to 0.2% (area 27) with an average percent grass cover of 19.9%. Percent grass cover in the two ripped areas ranged from 6.7% (area 29) to 6.5% (area 30) with an



a. Pitted areas



b. Pitted and seeded areas

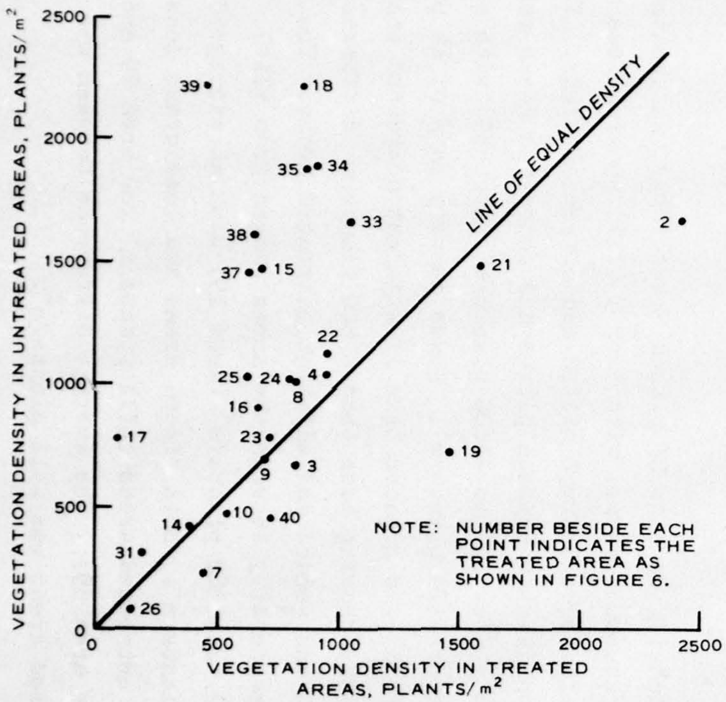
Figure 24. Comparison between percent grass cover in untreated and treated areas

average of 6.6%, which was less than the similar values for the other three conditions.

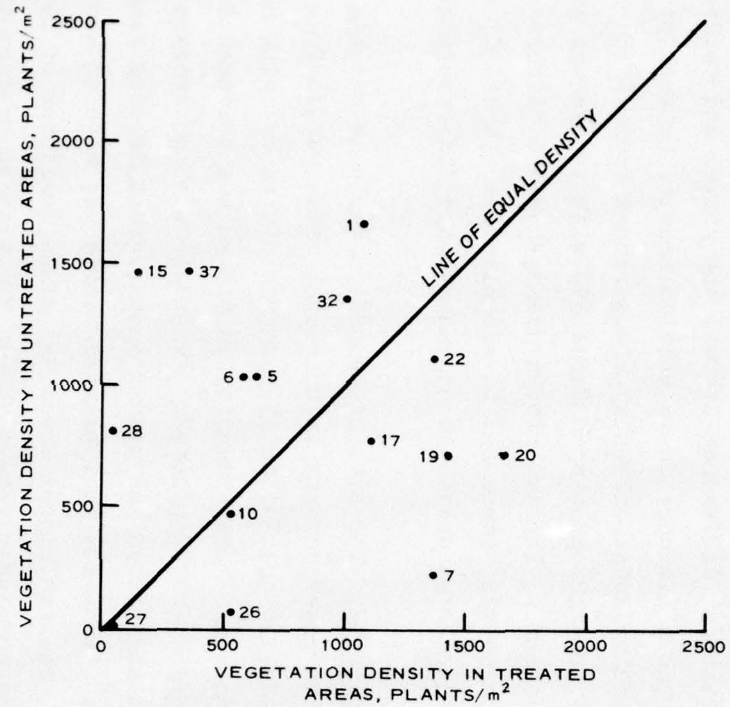
47. Figure 24 shows that in 5 of the 27 pitted areas (19%) the percent grass cover was equal to or greater in the pitted area as compared with the adjacent untreated area with 4 of the 5 sites (80%) showing an increase of 10% or less. The difference in percent grass cover (Table 12) in pitted areas varied from +16.6% in area 9 to -31.7% in area 35 with an average difference of -9.7%. Percent grass cover in pitted and seeded areas was greater than in untreated areas in 6 of 15 areas (40%) with 4 of the 6 areas (67%) showing an increase in percent grass cover of 10% or more. The difference in percent grass cover in pitted and seeded areas varied from +32.1% in area 7 to -26.9% in area 15 with an average difference of -2.6%. Both ripped areas showed a decrease in percent grass cover as compared with the untreated areas (-17.7% in area 29 and -2.1% in area 30) with an average decrease of -9.9%.

48. Vegetation density. A study of Table 13 and Figure 25 reveals the similarity between the vegetation density in the treated and untreated sites. For example, vegetation density in untreated areas ranged from 2242 plants/m^2 (areas 18 and 39) to 22 plants/m^2 (area 27) with an average of 1047 plants/m^2. Vegetation density in pitted areas ranged from 2431 plants/m^2 (area 2) to 101 plants/m^2 (area 17) with an average of 799 plants/m^2. The maximum vegetation density in pitted and seeded areas was 1658 plants/m^2 (area 20), and the minimum was 44 plants/m^2 (areas 27 and 28). Vegetation density in ripped areas ranged from 389 plants/m^2 (area 30) to 314 plants/m^2 (area 29) with an average of 352 plants/m^2.

49. Vegetation density in 9 of 27 pitted areas (33%) was equal to or greater than in adjacent untreated areas with 7 of 9 (78%) showing less than a 500 plants/m^2 difference between the pitted and untreated areas. The difference in vegetation density between pitted and untreated areas ranged from +749 plants/m^2 (area 19) to -1770 plants/m^2 (area 39) with an average difference of -300 plants/m^2. Vegetation density in 8 of 15 (53%) pitted and seeded areas was greater



a. Pitted areas



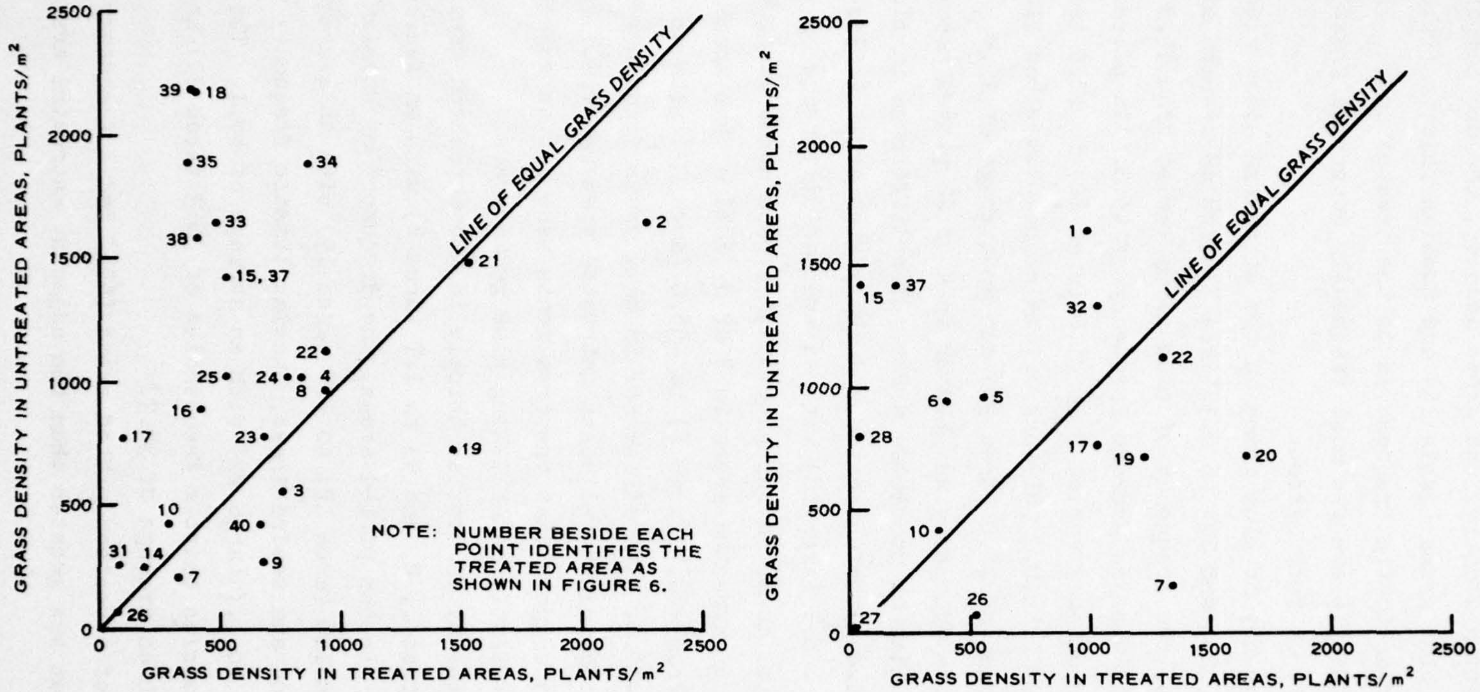
b. Pitted and seeded areas

Figure 25. Comparison between vegetation density in untreated and treated areas

than vegetation density in untreated areas with 5 of 8 (63%) showing less than a 500 plants/m^2 difference between the pitted and seeded and untreated areas. The difference in vegetation density between pitted and seeded areas and adjacent untreated areas ranged from +1132 plants/m^2 (area 7) to -1122 plants/m^2 (area 37) with an average difference of -43 plants/m^2. The two ripped areas showed a difference ranging from -680 plants/m^2 (area 29) to +76 plants/m^2 (area 30) when compared with the untreated areas and had an average difference of -302 plants/m^2.

50. Grass density. The data presented in Table 14 and Figure 26 indicate that grass density in untreated areas ranged from 2191 plants/m^2 (areas 18 and 39) to 15 plants/m^2 (area 27) with an average of 997 plants/m^2. Grass density in pitted areas ranged from 2267 plants/m^2 (area 2) to 70 plants/m^2 (area 26) with an average of 667 plants/m^2. In the pitted and seeded areas, grass density ranged from 1640 plants/m^2 (area 20) to 1 plant/m^2 (area 27) with an average of 707 plants/m^2. The two ripped areas had grass densities of 255 plants/m^2 (area 29) and 144 plants/m^2 (area 30) with an average of 199 plants/m^2.

51. Grass density in 7 of 27 pitted areas (26%) was greater than in adjacent untreated areas, with 5 of 7 (71%) showing less than a 500 plants/m^2 difference between pitted and untreated areas. The difference in grass density between pitted and untreated areas ranged from +744 plants/m^2 (area 19) to -1800 plants/m^2 (area 39) with an average difference of -378 plants/m^2. Grass density in 6 of 14 pitted and seeded areas (43%) was greater than in adjacent untreated areas with 3 of the 6 (50%) showing less than a 500 plants/m^2 difference between the pitted and seeded and adjacent untreated areas. The difference in grass density between the areas ranged from +1147 plants/m^2 (area 7) to -1382 plants/m^2 (area 15) with an average difference of -134 plants/m^2. Both ripped areas had less grass density than the adjacent untreated areas (-711 plants/m^2 for area 29 and -115 plants/m^2 for area 39). The average difference between the ripped and untreated areas was -413 plants/m^2.



a. Pitted areas

b. Pitted and seeded areas

Figure 26. Comparison between grass density in untreated and treated areas

52. Frequency. In addition to percent vegetation cover, percent grass cover, vegetation density, and grass density, the WES compared the frequencies of blue grama (Table 15) and Russian thistle (Table 16) in the untreated areas to the frequencies in the treated areas. Blue grama and Russian thistle are the most frequently occurring grass and dicot, respectively, on Fort Carson.

53. The frequency of blue grama in the untreated sites ranged from 100 (areas 19, 20, and 22) to 0.3 (area 7) with an average of 62.0. In the pitted areas, the frequency of blue grama varied from 86.3 (area 22) to 0.7 (area 35) with an average frequency of 45.5. In pitted and seeded areas, the frequency varied from 87.0 (area 22) to 17.0 (area 10) with an average of 56.0. Only one of the ripped sites had blue grama with a frequency of 15.0 (area 30) and an average of 15.0.

54. Blue grama frequency was higher in 4 of 22 pitted areas (18%) than in the adjacent untreated areas. The difference in blue grama frequency between the untreated and the pitted areas varied from +43.0 (area 34) to -68.7 (area 18) with an average difference of -19.0. The frequency of blue grama in the pitted and seeded areas was greater than in the adjacent untreated areas in 3 of 8 (38%) of the areas. The difference varied from +68.4 (area 7) to -55.0 (area 37) with an average difference of -10.0. The difference in blue grama frequency between the ripped area and the adjacent untreated area was +13.7 (area 30). These results suggest that the treatments were not as successful as desired in consistently establishing blue grama grass.

55. The frequency of Russian thistle in the untreated areas varied from 100 (areas 1, 2, and 9) to 1.7 (area 8) with an average frequency of 37.8. In the pitted areas, the frequency of Russian thistle varied from 100 (area 10) to 0.7 (area 19) with an average of 33.4. In the pitted and seeded areas, Russian thistle frequency varied from 96.7 (area 6) to 1.7 (area 22) with an average of 48.1. The two ripped areas had Russian thistle frequencies of 38.3 (area 29) and 27.0 (area 30) with an average of 32.7.

56. Eleven of seventeen pitted areas (65%) had a frequency of Russian thistle that was greater than the adjacent untreated areas. The

frequency difference varied from +76.7 (area 10) to -98.2 (area 9) with an average frequency increase of +3.7. Five of eight pitted and seeded areas (62%) had greater Russian thistle frequency than the adjacent untreated areas. The frequency differences varied from +73.3 (area 15) to -42.6 (area 5) with an average difference of +16.6. The difference in frequency between the ripped and the adjacent untreated areas varied from +27.0 (area 29) to -8.3 (area 30) with an average of +9.4.

57. Maximum height. Table 17 presents a comparison of the maximum heights of blue grama in the untreated and treated areas. The maximum height varied from 50 cm (area 8) to 3.0 cm (area 7) with an average of 19.0 cm in untreated areas. In the pitted areas, the maximum height varied from 47.0 cm (area 10) to 1.0 cm (area 17) with an average of 21.8 cm. In the pitted and seeded areas, the maximum height varied from 57.0 cm (area 26) to 8.0 cm (area 10) with an average of 31.0 cm. Blue grama occurred in only one ripped area (area 30) with a maximum height of 41.0 cm. The difference in maximum height between the pitted and the untreated areas varied from +24.0 cm (area 24) to -31.0 cm (area 35); the average difference was +0.7 cm. The difference in maximum heights between the pitted and seeded and the untreated areas varied from +31.0 cm (area 7) to -36.0 cm (area 10) with an average difference of +10.4 cm. The maximum height in the ripped area (area 30) was +34.0 cm greater than the adjacent untreated area.

58. Average height. Table 18 presents a comparison of the average heights of the vegetative stems of blue grama in the untreated and treated areas. Average heights in the untreated areas varied from 15.7 cm (area 8) to 0.7 cm (area 7) with a mean average height of 4.0 cm. In the pitted areas, the average heights of blue grama varied from 7.7 cm (area 8) to 1.0 cm (area 17) with a mean average height of 4.0 cm. In the pitted and seeded areas, the average heights varied from 8.4 cm (area 26) to 1.7 cm (areas 17 and 37) with a mean average of 4.5 cm. The average height of blue grama in the one ripped area (area 30) of occurrence was 7.7 cm. The difference in average heights between the pitted and the untreated areas varied from +3.3 cm (area 33) to -8.4 cm (area 35) with a mean average height difference between

the areas of -0.5 cm. The average height difference between the pitted and seeded and the untreated areas varied from +7.6 cm (area 7) to -2.7 cm (area 10) with a mean average height difference of -1.6 cm. The average height in the ripped area (area 30) differed from that in the adjacent untreated area by +6.0 cm.

59. Flowering or fruiting. Table 19 lists the number of untreated and treated areas in which flowering or fruiting structures were present on blue grama. The results indicate that blue grama was potentially sexually reproducing in 48% of the pitted areas, 40% of the pitted and seeded areas, 50% of the ripped areas, and 61% of the untreated areas.

60. Grass seeding. The WES compared the grass species present on the pitted and seeded areas in 1977 to the grass species that were seeded on the areas and the number of years between seeding and sampling (Table 20). The number of areas seeded with each species was then compared with the number of areas in which the species was still present in 1977, and the percent of areas showing successful seeding was calculated (Table 21). The results indicate that blue grama, a native grass, succeeded in 75% of the areas seeded; pubescent and crested wheatgrass, both adapted species, succeeded in 33 and 40%, respectively, of the areas seeded; Russian wildrye, an adapted species, succeeded in 20% of the areas seeded; and slender wheatgrass, western wheatgrass, and side-oats grama seedings failed. The number of years since the seedings did not appear to be significant because when blue grama seedings (for which the longest planting records exist) were compared, one was successful and one was a failure after six years.

Summary of results

61. If the restoration treatments were to be considered successful, the posttreatment data on the vegetation factors (percent vegetation cover, percent grass cover, vegetation density, grass density, frequency, maximum height, average height, and flowering or fruiting) in all the treated areas should have approached or shown an increase in those factors when compared with the adjacent untreated areas that have similar soils, slopes, and elevations. As stated in paragraph 35,

the vegetation conditions in the untreated areas were assumed to be representative of the native vegetation conditions that would have occurred in the treated areas if they had not been pitted, pitted and seeded, or ripped, or had not undergone military vehicle-induced damage.

62. Pitting treatments. The results of the WES sampling program (see paragraphs 38-60) indicate that pitting treatments had resulted in greater percent vegetation cover in 41% of the pitted areas, greater percent grass cover in 19% of the pitted areas, greater vegetation density in 33% of the pitted areas, greater grass density in 26% of the pitted areas, higher frequency of blue grama in 18% of the pitted areas, greater Russian thistle in 65% of the pitted areas, greater height of blue grama in 59% of the pitted areas, greater average height of blue grama in 45% of the pitted areas, and 13 percent less areas in which blue grama was flowering or fruiting. Thus, depending upon the factor selected as the indicator of successful treatment, pitting resulted in vegetation being restored to conditions of the untreated areas from -13 to 65% of the areas treated.

63. Further, it should be noted that the effects of pitting on the native or adapted perennial grasses are often not visible for one or two years.* The first evidence of increased soil moisture is an increase in the number and height of annual weeds and grasses followed gradually by increased vigor and seed production in the perennial grasses on the edge of the pits. In a series of dry years, the benefits of the treatment may not be visible for as long as three to four years.

64. Pitting and seeding treatments. Pitting and seeding treatments resulted in greater vegetation cover in 46% of the pitted and seeded areas, greater percent grass cover in 40% of the areas, greater vegetation density in 53% of the areas, greater grass density in 43% of the areas, higher frequency of blue grama in 38% of the areas, higher frequency of Russian thistle in 62% of the areas, greater maximum height of blue grama in 88% of the areas, greater average height of

* Personal communication with Durwood Davis, Land Management Branch, Fort Carson, Colorado.

blue grama in 62% of the areas, and 21% less areas in which blue grama was flowering or fruiting. Based on the indicators selected by Fort Carson, pitting and seeding was successful from -21 to 86% in the areas treated.

65. Ripping treatments. Only two areas on Fort Carson had been ripped at the time of sampling in July 1977. One area had more percent vegetation cover than the untreated area and one area did not. Both areas had less percent grass cover than the untreated areas. Vegetation density was less in one area and greater in the other. Grass density was less in both areas. Frequency of blue grama in the one site containing blue grama was more; maximum height and average height were greater. Frequency of Russian thistle increased in one area and decreased in the other. Not enough data on ripped areas was available to determine conclusively whether ripping treatments were successful on Fort Carson. Land management personnel report that the soil surface condition that results from ripping is an effective runoff and wind erosion control for one to two years before natural weathering reduces its effectiveness. During rainy periods, the soil retains enough moisture to mire even four-wheel-drive vehicles.

66. Review of the data presented in preceding paragraphs (41 to 65) and Tables 6-21 shows that the treatments were beneficial in certain instances. However, the degree of success varied from site to site, and in some cases the treated sites had considerably less vegetation than the untreated. For example, refer to paragraph 43 and Table 11 wherein the percent vegetation cover was 24% less (area 34) than the untreated site. For this reason, the vegetation data were analyzed with respect to precipitation and the terrain conditions shown in Table 3, i.e. soil class, slope, and elevation, to see if the success of the treatments could be correlated to site conditions. The following paragraphs discuss this analysis.

Analysis of environmental factors

67. Perhaps the most important factors affecting successful vegetation establishment are adequate precipitation and good cultural methods. Precipitation (rainfall or snowfall) is necessary for seed

germination and survival of young seedlings. Survival of the desired grasses would be severely reduced if pitting, pitting and seeding, or ripping were done in years with low precipitation since the germinating seeds and seedling plants would be put under additional stress. Some considerations of precipitation and site conditions (terrain and use) are discussed below.

68. Precipitation. At present, detailed precipitation records in the treated areas are not available for correlation with cover or density data. To provide some insight into this problem, the WES obtained annual precipitation* data from the National Climatic Center[18] for three weather stations within a 30-mile (48.3-km) radius of Fort Carson and for the weather station at Butts Airfield on Fort Carson. From these data, the minimum, maximum, and average annual precipitation for the total number of years the stations were in operation was determined (Table 22). These four stations (Colorado Springs Airport, Fountain, Pueblo Airport, and Butts Airfield) had continuous annual precipitation records for the six-year period (1971-1976) since seeding had begun at Fort Carson. The annual precipitation data for the four stations were used to calculate the six-year average and the combined average annual precipitation for the six years (Table 23). A comparison between the six-year average annual precipitation for the four stations and the station average annual precipitation for the four stations over all operating years shows that all stations received less annual precipitation during the six years (Table 23). The weather station at Fountain showed 2.69 in. less annual precipitation during the six years than the station average (the maximum difference), and the station at Butts Airfield showed 0.25 in. less (the minimum difference); however, the six-year mean annual precipitation for the four stations combined was only 0.89 in. less than the station mean annual precipitation for the four stations combined (all operating years).

69. The WES established three weather stations on Fort Carson in 1976 to study the amount and distribution of rainfall on the reservation

---

* Total annual rainfall and snowfall.

(described in detail in Report 2 of this series). Figure 27 shows the locations of these three stations (Clover Ditch, Red Devil, and Turkey Creek) with respect to the four stations discussed in paragraph 68.

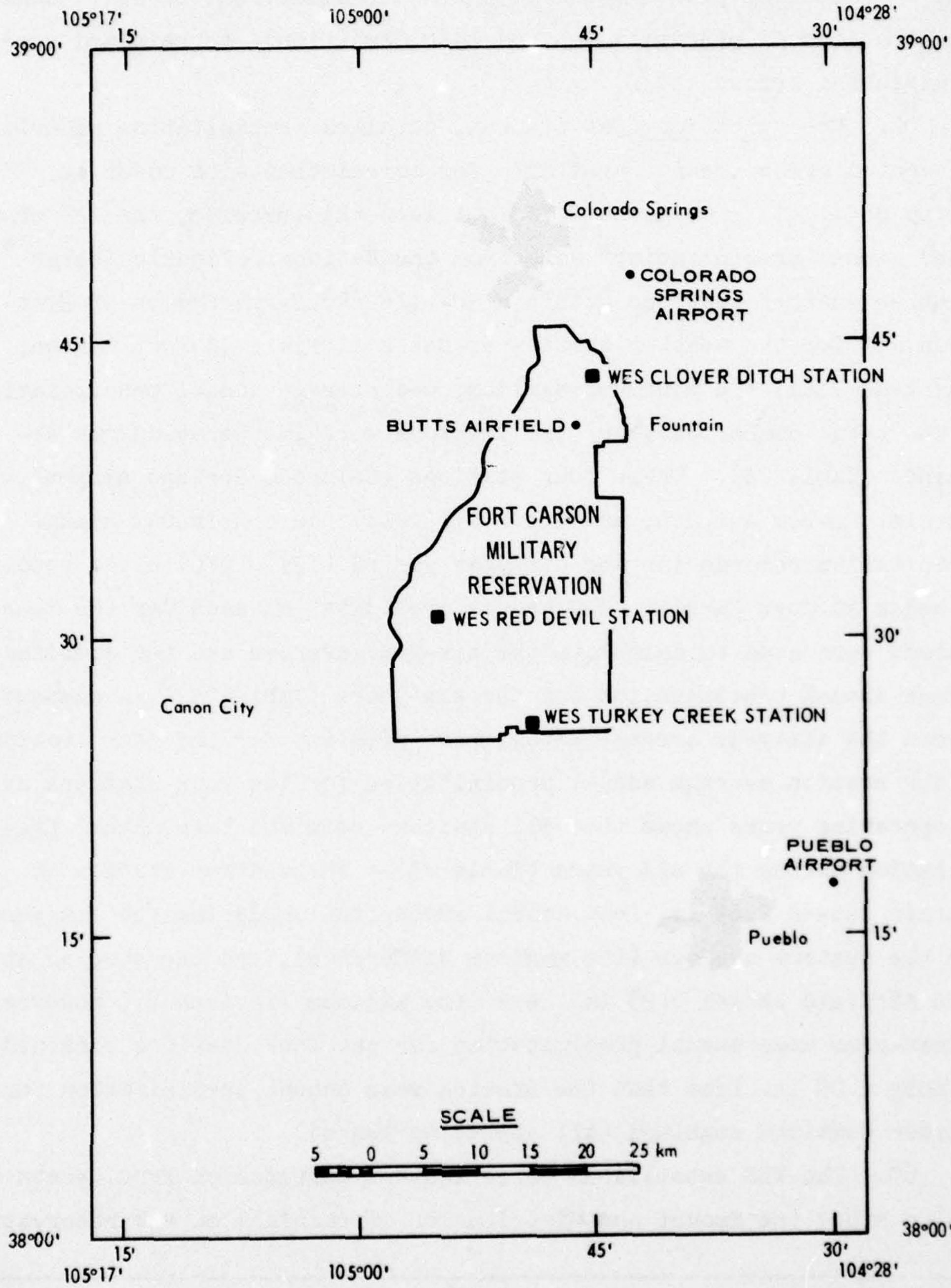


Figure 27. Locations of weather stations

From Table 24, examples of the variability in rainfall recorded at all seven stations on selected days in 1976 can be ascertained. Table 25 shows the distance in statute miles between the seven stations. The annual (Table 23) and selected daily (Table 24) precipitation data indicate that the rainfall on Fort Carson is extremely variable in amount and distribution in the Fort Carson area. For example, in 1976 Colorado Springs Airport (7.6 miles from Fountain) received 20.34 in. of precipitation while Fountain received 8.65 in.; and on 6 June 1976, Clover Ditch (3 miles from Fountain) received 1.04 in. of rainfall while Fountain received 0 in. It is almost certain that none of the precipitation data (annual or daily) from the seven weather stations accurately reflect the actual precipitation received at any of the treated areas on Fort Carson. Thus, no direct comparisons can be made between the precipitation history at a weather station and the present vegetation in the treated areas. However, a comparison (Table 26) of the combined average annual precipitation (average of the four stations for each of the six years) as listed in Table 23 (designated "combined average annual precipitation") and the combined mean of the station average annual precipitation as listed in Table 22 (designated "combined mean annual precipitation") shows that in four (1971, 1973, 1974, and 1975) of the six years, annual precipitation in the Fort Carson area was below the mean annual precipitation and that as much as 2.5-in. less annual precipitation was received in 1971 and 1974 than the mean annual precipitation. Thus, the poor conditions of the grass stands in 1977 could have been due to insufficient moisture.

70. To determine if precipitation could be shown to be correlated to an increase or decrease in the vegetation in the treated areas, the WES compared the year an area was treated with the four major vegetation factors (percent vegetation cover, percent grass cover, vegetation density, and grass density) measured in the pitted areas (Table 27), pitted and seeded areas (Table 28), and the ripped areas (Table 29). A definite trend was not discernible in these comparisons, i.e., the year an area was treated (and thus the rainfall in that year) could not be shown to be correlated to an increase or decrease in vegetation

cover in treated sites. Since precipitation was known to be important to vegetation on Fort Carson, the probable reason for the lack of correlation is the fact that detailed precipitation data were not available for the treated areas.

71. Supplemental irrigation. Since distribution and amounts of precipitation were so variable on Fort Carson, the WES investigated the possibility that supplemental irrigation could be used to irrigate selected seeded areas on Fort Carson. This cultural practice is not practical on Fort Carson, however, because the water supply in the downrange areas is very limited and is insufficient for irrigation purposes. The only permanent surface water supply is Teller Reservoir, which is maintained for recreation (warm water fishing). Land management personnel indicate that the yearly precipitation in the watershed above Teller Reservoir is barely adequate to maintain the desired water levels in the reservoir and thus could not be used as a source of irrigation water. Downrange wells do exist (see Report 1), but the adjudicated water rights law of the state of Colorado regulate all water resources and are very restrictive as to the establishment of new wells. Fort Carson land management personnel indicate that a request to the state for permission to drill irrigation wells is likely to be refused.

72. Effects of terrain conditions. An analysis was made to determine if soils, slopes, and elevations in the treated areas could be correlated with an increase or decrease in the four major vegetation factors--percent vegetation cover, percent grass cover, vegetation density, and grass density--in the pitted areas (Table 27), in pitted and seeded areas (Table 28), and ripped areas (Table 29). The results of this analysis indicate that of the three terrain conditions, only elevation appeared to have even a slight correlation with the vegetation factors (Figure 28). As elevation increased in the treated areas, all four of the vegetation factors decreased in the treated areas.

73. This does not mean, however, that site conditions are not important considerations in designing restoration treatments (e.g.,

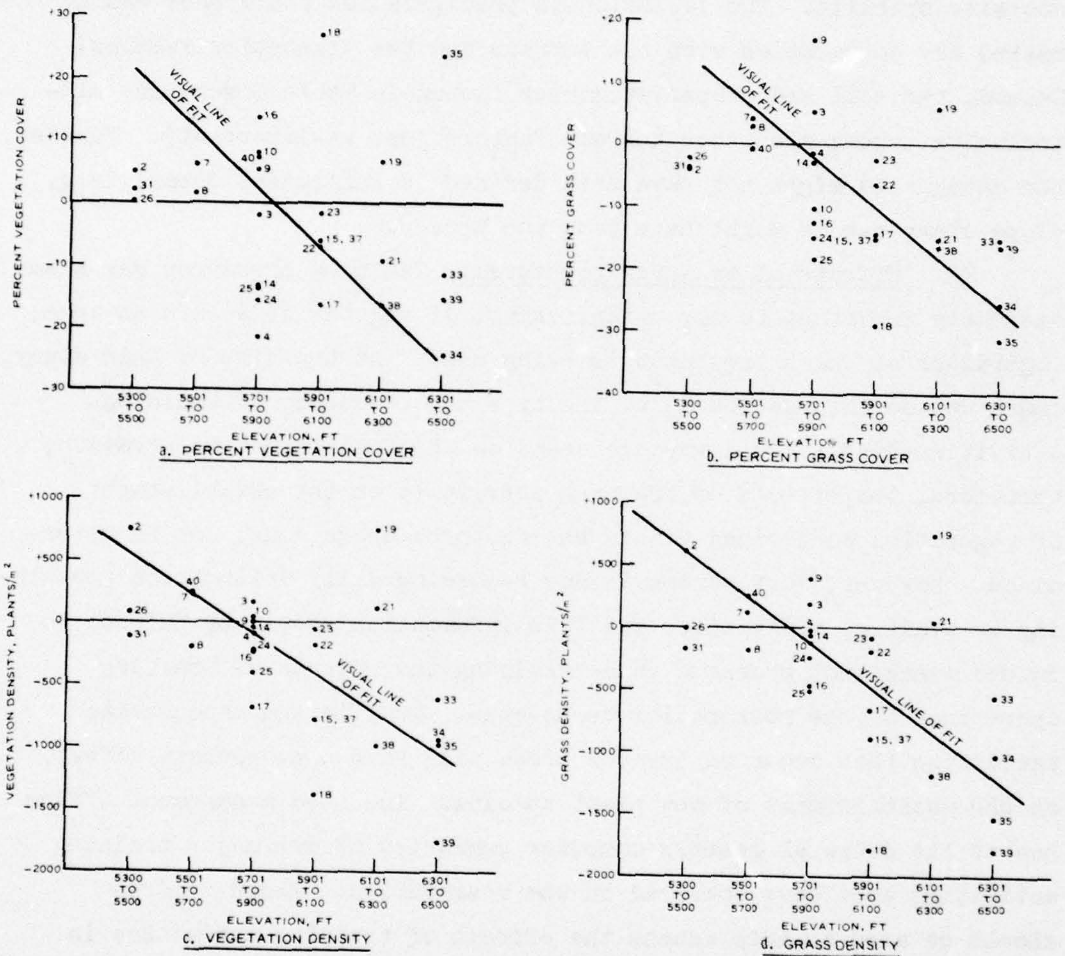


Figure 28. Correlation between elevation and increase or decrease in the four vegetation factors as a result of pitting

pitting would not be a satisfactory restoration technique on pervious sandy soil because it could not retain water). It is assumed that correlations of treatment results and site conditions could not be established at Fort Carson for two reasons. First, the precipitation probably had the most impact on vegetation regrowth, but the data were not site specific. The variation in precipitation could have easily masked any correlation with the terrain and the vegetation factors. Second, the soil and slope categories listed in Table 3 were not all-inclusive (there are other terrain factors just as important). Further, the categories might not have been defined in sufficient detail (e.g., slope class ranges might have been too broad).

74. Effects of training pressures. Training pressures are also extremely important to the establishment of vegetation within an area, regardless of which treatment is being used. At the time of this study, there was no information as to the type and frequency of training activities within the downrange areas on the Fort Carson reservation; therefore, the effects of training activities on the establishment of vegetation conditions within the restored areas could not be determined. However, Fort Carson is now recording daily information pertaining to training activities, and this information should be helpful to future management programs in determining the effects of training operations on the restoration techniques. Traffic and maneuvering activities that occur on treated areas will have a pronounced effect on the establishment of new plant species. The Land Management Office has at its disposal monthly computer summaries of all major training activities that have occurred on the reservation. These reports should be used to help assess the effects of training activities in those areas that have been treated and in areas where treatment is planned.

Discussion

75. Grass cover on Fort Carson is a desired condition that has been encouraged artificially by pitting with seeding at a number of the treated sites. At present, a little over a dozen grass species are commonly encountered on the reservation. Among these species

there is a frequent occurrence of blue grama (Bouteloua gracilis), ring muhly (Muhlenbergia torreyi), alkali sacaton (Sporobolus airoides), squirrel tail (Sitanion hystrix), and red three awn (Aristida longiseta) (Tables 6-9). Each of these five species is successful over large areas of the reservation and should probably be considered as tolerant native species for use in future seeding studies. Pitting, when used alone, would probably yield good results in those areas where a well-established seed source is in existence.* In the absence of an adequate seed source, it is recommended that the seeds of species to be introduced be sown as mixtures with seeds from native species that are successful in the Fort Carson area. These successful species are listed above. In future treatment planning, every attempt possible should be made to provide selected sites that allow for long-range assessment of the effects of pitting, pitting with seeding, ripping, or other practices that are employed. Control sites, where no treatment is performed, should be included wherever a comparison of treatment effectiveness will be needed. Also, prior to any treatment, the acquisition of baseline vegetation data on plant cover, grass cover, and densities should be made. Detailed rainfall records for sites that have been treated and where revegetation evaluations will be made are extremely valuable in assessing the success of the treatment employed.

Evaluation of the Mechanical Restoration Methods

Sediment basins

76. The literature survey (Appendix A) indicated that sediment basins and their associated dams are effective erosion control structures, which have been successfully used to intercept and retain sediment. Since the sediment basins on Fort Carson conform to SCS standards, they are considered to be effectively constructed for erosion control. Report 4 of this series describes detailed studies that were performed on six sediment basins and their associated watersheds to develop a

---

* Personal communication with Don Neilson, USDA-SCS.

relationship between soil loss, watershed characteristics, and land use practices.

Debris dams

77. In the literature reviewed by the WES, debris dams were identified as effective barriers to water flow and sediment transport in gullies. They function both as sediment retention structures (traps) and, when sediment builds up in front of the traps, as grade control structures. The effectiveness of the debris dams built on Fort Carson in 1976 (see paragraphs 22-24) could not be determined at the time of this report.

Restricted areas

78. The effectiveness of placing areas of Fort Carson "off limits" to training activities depends upon the degree to which troop commanders cooperate with the Land Management Branch, DFAE, in controlling the movement of tracked and wheeled vehicles and troop personnel. Since this will vary among commanders, only long-term changes in the restricted areas can be assessed. The techniques previously described in WES Technical Report M-74-8[2] (which determine intensity of use of an area) should be applied at about two-year intervals to determine the effectiveness of the "off limits" restrictions. The cost of this method of allowing vegetative cover to become reestablished includes the cost of preparing maps of restricted areas for distribution to troop commanders and the cost due to loss of the use of those areas for training. Ideally, the reservation should have a sufficient number of training areas to allow a rotation period long enough for vegetation to recover naturally. Land management personnel, however, have indicated that there is currently not enough land on Fort Carson to support a rotation program and that the recovery period could be as long as 5 to 10 years. The proposed expansion of Fort Carson, however, could provide enough additional training areas for rotation.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

79. Land management personnel at Fort Carson have pitted 6179 acres, pitted and seeded 2078 acres, and ripped 83 acres in an attempt to establish vegetation in selected areas (see paragraphs 9-14). Pitting and pitting and seeding were found to be successful treatments since treated areas had greater percent vegetation cover, percent grass cover, vegetation density, and grass density than the untreated areas (see paragraphs 62-64). Not enough data on ripped areas were available to determine if ripping was successful (see paragraphs 65 and 66). Native grasses appear to be more successful than adapted grasses in seeded (see paragraph 60) and untreated areas (see paragraph 75).

80. Distribution and amount of precipitation were found to vary widely in the Fort Carson area and could not be correlated to either success or failure of treatments because site specific data were not available on precipitation received on each of the treated areas (see paragraphs 68-70). Supplemental irrigation of the downrange areas was not considered practical because the downrange water supplies were inadequate or could not be used for irrigation (see paragraph 71).

81. Of the three terrain factors investigated (soils, slopes, and elevations), only elevation was found to be correlated to increases or decreases in the vegetation (see paragraph 72).

82. Placing selected areas of Fort Carson "off limits" to wheeled and tracked vehicles can potentially increase vegetation in those areas, but not enough training areas exist on Fort Carson to allow rotation with sufficient time between use for vegetation to recover. The proposed expansion of Fort Carson would provide the additional training areas needed for rotation (see paragraph 78).

Recommendations

83. In order to more effectively control soil erosion on Fort Carson, it is recommended that:

a. Pitting be continued to retain additional soil moisture in areas containing native perennial grasses (seed sources) free of competing vegetation.

b. All pitted and ripped areas should be seeded with native perennial grasses.

c. The limitations on training in restricted areas be vigorously enforced and biennial assessment of the intensity of use of the areas be made.

d. Additional rainfall stations be established in those areas for which restoration effectiveness studies are to be conducted.

e. A determination be made of the effects of military training on the restoration procedure being used for the establishment of vegetation cover.

f. Effectiveness studies be continued to determine the long-range effects of different restoration techniques. Control plots should be established for comparison with plots established in the restored areas.

REFERENCES

1. Headquarters, Fort Carson and 4th Infantry Division, "Fort Carson Environmental Program," FC and 4D Regulation No. 200-1, 1975, Fort Carson, Colo.

2. Cress, D. H. and Link, L. E., Jr., "The Use of Remote Sensing Systems for Acquiring Data for Environmental Management Purposes; Application of Photographic Remote Sensors to an Environmental Management Problem," Technical Report M-74-8, Report 2, May 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

3. Stokes, C. M., Larson, F. D., and Pearse, C. K., "Range-Improvement Through Waterspreading," p 36, 1954, U. S. Government Printing Office, Washington, D. C.

4. Elkins, A., "Erosion Map (Fort Carson Area)," 1976, Soil Conservation Service, Department of Agriculture, Denver, Colo.

5. Soil Conservation Service, "Range Seeding," Technical Guide Series, Section IV, No. 550, 1971, Department of Agriculture, Washington, D. C.

6. __________, "Seeding Rates," Technical Guide Series, Section V (Unnumbered), 1976, Department of Agriculture, Washington, D. C.

7. Office of Water Planning and Standards, "Methods of Quickly Vegetating Soils of Low Productivity, Construction Activities," EPA Report No. 440/9-75-006, p 467, Jul 1975, U. S. Environmental Protection Agency, Washington, D. C.

8. Smartt, P. R. M., Meacock, W. E., and Lambert, J. M., "Investigations into the Properties of Quantitative Vegetational Data," Journal of Ecology, Vol 62, No. 3, 1974, pp 735-759.

9. Oosting, H. J., The Study of Plant Communities, W. H. Freeman, San Francisco, Calif., 1950.

10. Phillips, E. A., Methods of Vegetation Study, Henry Holt, New York, 1959.

11. Ellison, L., "A Comparison of Methods of Quadratting Short-Grass Vegetation," Journal of Agricultural Research, Vol 64, No. 10, May 1942, pp 594-614.

12. Snedecor, G. W., Statistical Methods Applied to Experiments in Agriculture and Biology, Iowa State College Press, Ames, Iowa, 1953.

13. Cain, S. A., "The Species-Area Curve," American Midland Naturalist, Vol 19, 1938, pp 573-581.

14. Greig-Smith, P., Quantative Plant Ecology, 2nd ed., Butterworth, Washington, D. C., 1964.

15. Cain. S. A. and de Oliverira Castro, G. M., Manual of Vegetation Analysis, Harper, New York, 1959.

16. Harrington, H. D., Manual of the Plants of Colorado, Swallow Press, Chicago, 1964.

17. Hitchcock, A. S., Manual of the Grasses of the United States, Miscellaneous Publication 200, Department of Agriculture, Washington, D. C., 1950.

18. National Climatic Center, "Climatological Data," Vol 5, No. 1-12, 1976, Department of Commerce, Asheville, N. C.

19. Woodruff, N. P. et al., "How to Control Wind Erosion," No. 354, Jun 1972, Agricultural Research Service, Department of Agriculture, Washington, D. C.

20. Johnson, W. M. and Hull, A. C., Jr., "How to Reseed Parks and Openings in the Ponderosa Pine Zone in Colorado," Jun 1950, Rocky Mountain Forest and Range Experiment Station, U. S. Forest Service, Department of Agriculture, Fort Collins, Colo.

21. Lavin, F. and Springfield, H. W., "Seeding in the Southwestern Pine Zone for Forage Improvement and Soil Protection," Agriculture Handbook No. 89, Oct 1955, U. S. Forest Service, Department of Agriculture, Washington, D. C.

22. Hull, A. C., Jr., et al., "Seeding Colorado Range Lands," Bulletin 498-5, 1958, Colorado State University Experiment Station, Fort Collins, Colo.

23. Springfield, H. W., "Characteristics and Management of Southwestern Pinyon-Juniper Ranges: The Status of Our Knowledge," Research Paper RM-160, Aug 1976, Rocky Mountain Forest and Range Experiment Station, U. S. Forest Service, Department of Agriculture, Fort Collins, Colo.

24. Wight, J. R., "Land Surface Modifications and Their Effects on Range and Forest Watersheds, in Watershed Management on Range and Forest Lands," Proceedings, Fifth Workshop of the United States/Australia Rangelands Panel, Jun 15-22, 1975, Boise, Idaho, 1976, pp 165-173.

25. Wight, J. R. and White, L. W., "Interseeding and Pitting on a Sandy Range Site in Eastern Montana," Journal of Range Management, Vol 27, No. 3, 1974, pp 206-210.

26. Wight, J. R. and Siddoway, F. H., "Improving Precipitation-Use Efficiency on Rangeland by Surface Modification," Journal of Soil and Water Conservation, Vol 27, No. 4, Jul-Aug 1972, pp 170-174.

27. Soil Conservation Service, "Critical Area Planting," Technical Guide Series, Section V, No. 342, Department of Agriculture, Washington, D. C.

28. Soil Conservation Service, "Subdivision Regulations," Technical Guide Series, Section V, El Paso County Revegetation Specifications, Department of Agriculture, Washington, D. C.

29. Wight, J. R., "Range Fertilization in the Northern Great Plains," Journal of Range Management, Vol 29, No. 3, 1976, pp 180-185.

30. Williams, C. L., "Mulches for Critical Areas," Agronomy Note No. 147, 1973, Soil Conservation Service, Department of Agriculture, Washington, D. C.

31. Engdahl, T. L. and Rushing, W. N., "An Experiment in Fixed-Installation Camouflage, Aircraft Shelter Complex at Eglin Air Force Base, Florida," Miscellaneous Paper M-75-6, May 1975, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

32. Richey, C. B., Hall, C. W., and Jacobson, P., Agricultural Engineers' Handbook, McGraw-Hill, New York, 1961.

33. Bennett, H. H., Soil Conservation, McGraw-Hill, New York, 1939.

34. Miles, W. H., "Water Spreading," Soil Conservation, Vol 10, 1944, pp 73-76.

35. Keown, M. P. et al., "Literature Survey and Preliminary Evaluation of Streambank Protection Methods," Technical Report H-77-9, May 1977, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Table 1

Cost of Vegetation Improvement Methods Used at Fort Carson

Method	Estimated Cost* dollars/acre	dollars/km^2
Range pitting	5.57	(1376.35)
Range ripping	16.72	(4131.51)
Seeding		
Drilling seed**	11.94	(2950.37)
Hand broadcasting seed**	15.00	(3706.50)

* Estimated cost of treatments were obtained from Mr. Stan Ness, Land Management Branch, Fort Carson, Colorado.

** These costs do not include the costs of the grass seed, which average $4.00/lb ($8.81/kg) for native perennial grass seed and $1.00/lb ($2.20/kg) for adapted perennial grass seed.

Table 2

Data on Vegetation Reestablishment in Treated Areas

Area No.	Date Pitted or Ripped month/yr	Area Pitted or Ripped acres (km^2)	Date Seeded month/yr	Area Seeded acres (km^2)	Species Seeded (Common Name)	Seeding Rate lb/acre (kg/km^2)	Comments*
1	11/70	761 (3.04)	2/71	761 (3.04)	Blue grama	3-5 (340.5-567.5)	
2	11/69	1004 (4.02)	Not seeded	--	--	--	
3	11/74	310 (1.24)	2/75	70 (0.28)	Russian wildrye	5 (567.5)	Single-species seeding
					Pubescent wheatgrass	5 (567.5)	
4	11/69	115 (0.46)	Not seeded	--	--	--	
5	11/74	211 (0.84)	2/75	211 (0.84)	Pubescent wheatgrass	5 (567.5)	Single-species seeding
					Russian wildrye	5 (567.5)	
					Crested wheatgrass	5 (567.5)	
					Slender wheatgrass	5 (567.5)	
6	11/74	107 (0.43)	2/75	107 (0.43)	Pubescent wheatgrass	5 (567.5)	Single-species seeding
					Russian wildrye	5 (567.5)	
					Crested wheatgrass	5 (567.5)	
					Western wheatgrass	5 (567.5)	
7	11/74	96 (0.38)	2/75	30 (0.12)	Western wheatgrass	5 (567.5)	Mixed-species seeding
					Crested wheatgrass	5 (567.5)	
8	11/70	48 (0.19)	Not seeded	--	--	--	
9	11/69	87 (0.35)	Not seeded	--	--	--	
10	11/73	231 (0.92)	2/74	80 (0.32)	Crested wheatgrass	3-5 (340.5-567.5)	
11	11/72	67 (0.27)	Not seeded	--	--	--	
12	11/73	52 (0.21)	Not seeded	--	--	--	
13	11/73	15 (0.06)	Not seeded	--	--	--	
14	11/74	43 (0.17)	Not seeded	--	--	--	
15	11/74	234 (0.94)	2/75	70 (0.28)	Blue grama	10 (1135)	
16	11/74	91 (0.36)	Not seeded	--	--	--	
17	11/72	282 (1.13)	2/73	100 (0.4)	Blue grama	5 (567.5)	
18	11/72	187 (0.75)	Not seeded	--	--	--	
19	11/73	243 (0.97)	2/74	40 (0.16)	Blue grama	5 (567.5)	
	11/75	40 (0.16)	2/76	40 (0.16)	Side-oats grama	5 (567.5)	Repitted and seeded
20	11/73	67 (0.27)	2/74	67 (0.27)	Blue grama	3 (340.5)	Single-species seeding
					Pubescent wheatgrass	5-6 (567.5-681)	

(Continued)

* Single-species seeding refers to seeds of one species that are planted until supply is exhausted before another species is planted. Mixed-species seeding refers to a mixture of seeds of two or more species that are planted until supply is exhausted.

Table 2 (Concluded)

Area No.	Date Pitted or Ripped month/yr	Area Pitted or Ripped acres (km^2)	Date Seeded month/yr	Area Seeded acres (km^2)	Species Seeded (Common Name)	Seeding Rate lb/acre (kg/km^2)	Comments
21	11/73	91 (0.36)	Not seeded	--	--	--	
22	11/72	154 (0.62)	2/73	10 (0.04)	Blue grama	5 (567.5)	
23	11/72	350 (1.40)	Not seeded	--	--	--	
24	11/73	119 (0.48)	Not seeded	--	--	--	
25	11/73	91 (0.36)	Not seeded	--	--	--	
26	11/74	131 (0.52)	2/75	40 (0.16)	Pubescent wheatgrass	5 (567.5)	Single-species seeding
					Russian wildrye	5 (567.5)	
27	11/74	174 (0.70)	2/75	174 (0.70)	Russian wildrye	5 (567.5)	Single-species seeding
					Slender wheatgrass	5 (567.5)	
					Pubescent wheatgrass	5 (567.5)	
28	11/70	91 (0.36)	2/71	91 (0.36)	Blue grama	5 (567.5)	
29	11/74	43** (0.17)	Not seeded	--	--	--	
30	11/74	40** (0.16)	Not seeded	--	--	--	
31	11/74	36 (0.14)	Not seeded	--	--	--	
32	11/74	167 (0.67)	2/75	85 (0.34)	Crested wheatgrass	5 (567.5)	
				82 (0.33)	Crested wheatgrass	4 (454)	
					Yellow sweetclover	2 (227)	Mixed-species seeding
33	11/74	67 (0.27)	Not seeded	--	--	--	
34	11/74	24 (0.10)	Not seeded	--	--	--	
35	11/74	71 (0.28)	Not seeded	--	--	--	
36	11/74	91 (0.36)	Not seeded	--	--	--	
37	11/74	43 (0.17)	2/75	20 (0.08)	Blue grama	5 (567.5)	
38	11/75	91 (0.36)	Not seeded	--	--	--	
39	11/72	28 (0.11)	Not seeded	--	--	--	
40	11/73	29 (0.12)	Not seeded	--	--	--	
41	11/75	76 (0.30)	Not seeded	--	--	--	

** Ripped areas.

Table 3

Data on Terrain Conditions in Restored Areas

Area No.	USDA Textural Soil Classification	Slope Range %	Elevation, ft (m) Maximum	Minimum
1	Silty loam, loam	0-5	5520 (1683.6)	5420 (1653.1)
2	Silty loam, loam	0-5	5660 (1726.3)	5480 (1671.4)
3	Silty loam, clay loam, loam	0-5	5840 (1781.2)	5760 (1756.8)
4	Loam	5-10	5800 (1769.0)	5700 (1738.5)
5	Loam	0-5	5780 (1762.9)	5640 (1720.2)
6	Loam	0-5	5740 (1750.7)	5600 (1708.0)
7	Loam	0-5	5680 (1732.4)	5600 (1708.0)
8	Loam	0-5	5600 (1708.0)	5540 (1689.7)
9	Silty loam	5-10	5740 (1750.7)	5660 (1726.3)
10	Silty loam	0-5	5840 (1781.2)	5680 (1732.4)
11	Clay loam, loam	10-15	5620 (1714.1)	5540 (1689.7)
12	Loam	10-15	5740 (1750.7)	5640 (1720.2)
13	Loam	5-10	5800 (1769.0)	5740 (1750.7)
14	Clay, loam	5-10	5820 (1775.1)	5760 (1756.8)
15	Sandy loam	5-10	6000 (1830.0)	5940 (1811.7)
16	Sandy loam	5-10	5920 (1805.6)	5840 (1781.2)
17	Sandy loam	0-5	5960 (1817.8)	5880 (1793.4)
18	Fine sandy loam	0-5	6080 (1854.4)	5920 (1805.6)
19	Fine sandy loam, loam	5-10	6280 (1915.4)	6000 (1830.0)
20	Loam	0-5	6200 (1891.0)	6120 (1866.6)
21	Fine sandy loam, loam	5-10	6160 (1878.8)	6120 (1866.6)
22	Fine sandy loam	0-5	6160 (1878.8)	6040 (1842.2)
23	Fine sandy loam	0-5	6000 (1830.0)	5880 (1793.4)
24	Silty loam, loam	0-5	5880 (1793.4)	5880 (1769.0)
25	Silty loam, loam	5-10	5880 (1793.4)	5800 (1769.0)
26	Loam, clay loam	0-5	5400 (1647.0)	5320 (1622.6)
27	Clay loam	0-5	5640 (1720.2)	5560 (1695.8)
28	Loam	0-5	5920 (1805.6)	5880 (1793.4)
29	Loam, sandy loam	0-5	5500 (1677.5)	5480 (1671.4)
30	Loam, clay loam	0-5	5500 (1677.5)	5460 (1665.3)
31	Clay loam	0-5	5480 (1671.4)	5460 (1665.3)
32	Loam	0-5	6360 (1939.8)	6320 (1927.6)
33	Loam	0-5	6400 (1952.0)	6360 (1939.8)
34	Loam	0-5	6360 (1939.8)	6360 (1939.8)
35	Loam	0-5	6440 (1964.2)	6360 (1939.8)
36	Fine sandy loam	5-10	6400 (1952.0)	6320 (1927.6)
37	Sandy loam, loam	5-10	6000 (1830.0)	5960 (1817.8)
38	Loam	0-5	6080 (1854.4)	6160 (1878.8)
39	Fine sandy loam	0-5	6040 (1842.2)	6040 (1842.2)
40	Silty loam	0-5	5720 (1744.6)	5680 (1732.4)
41	Clay loam	5-10	5580 (1701.9)	5500 (1677.5)

Table 4

Characteristics of Impoundments

Identification Number	Location (Military Coordinates)	Approximate Water-Surface Area at Capacity, m^2	Classification	Identification Number	Location (Military Coordinates)	Approximate Water-Surface Area at Capacity, m^2	Classification
1	09385292	10,483	Sediment basin	41	22216082	20,967	Sediment basin
2	11705258	8,870		42	05906194	10,483	
3	13355213	5,645		43	13166179	7,258	
4	10375449	5,645		44	15856172	5,645	
5	15185469	374,999	Teller reservoir	45	15996188	6,451	
6	18695437	8,870	Sediment basin	46	17226116	4,032	
7	22305438	9,677		47	10646236	13,709	
8	07025503	11,290		48	11476240	26,612	
9	08485523	6,451		49	11726275	11,290	
10	09565568	9,677		50	12026208	18,548	
11	22395518	9,677		51	16186238	4,838	
12	04475615	6,451		52	19516238	4,032	
13	04695675	4,032		53	20496248	5,645	
14	04705699	5,645		54	07986327	14,516	
15	05555609	5,645		55	09186310	19,354	
16	05685642	4,032		56	13886345	8,064	
17	05575689	10,483		57	16276339	19,354	
18	09705670	6,451		58	17456395	10,483	
19	17445687	7,258		59	21216389	21,774	
20	05525772	2,419		60	09536457	11,290	
21	06145731	5,645		61	18766438	15,322	
22	08355752	6,451		62	19406433	9,677	
23	08565781	6,451		63	20046409	14,516	
24	06015879	8,064		64	04526421	4,838	
25	06015889	4,032		65	08726576	3,225	
26	06285853	5,645		66	12366598	9,677	
27	07555890	8,870		67	12926556	10,483	
28	08515843	9,677		68	16756529	13,709	
29	12735867	6,451		69	08736677	3,225	
30	15535878	8,064		70	12156655	11,290	
31	19555860	5,645		71	09906789	8,064	
32	09285920	10,483		72	10196748	3,225	
33	09295939	4,838		73	10756703	9,677	
34	15625958	6,451		74	13346708	8,870	
35	16295969	10,483		75	08686835	13,709	
36	17675984	18,548		76	08956963	8,064	
37	19215949	13,709		77	13677092	9,677	
38	18996016	3,225		78	08487144	5,645	
39	20436039	12,903		79	10507103	15,322	
40	22226003	9,677		80	10857169	4,383	

(Continued)

Table 4 (Concluded)

Identification Number	Location (Military Coordinates)	Approximate Water-Surface Area at Capacity, m^2	Classification
81	11927165	18,548	Sediment basin
82	09887268	6,451	
83	12867201	7,258	
84	09937347	5,645	
85	11057499	16,935	
86	20657823	2,419	
87	20757863	4,838	
88	21067858	12,903	Reservoir
89	21337825	8,870	Reservoir
90	18967914	6,451	Reservoir
91	19117909	33,870	Haymes Reservoir
92	20917962	40,322	North Side Reservoir
93	22378065	10,483	Fountain Reservoir
94	22558064	9,677	Reservoir
95	22668062	2,419	Reservoir
96	13408101	3,225	Sediment basin
97	14548135	13,709	Reservoir
98	14458149	29,838	Reservoir
99	17198128	41,128	Townsend Reservoir
100	23428165	12,903	Sediment basin
101	24428139	4,032	Sediment basin
102	14548208	8,064	Reservoir
103	19228291	4,032	Sediment basin
104	20788268	62,096	Sediment basin
105	23118219	17,741	Reservoir
106	16958375	4,838	Sediment basin
107	18128331	8,870	Sediment basin
108	23598465	6,451	Sediment basin
109	16748574	18,548	Reservoir
110	23258572	20,161	Sediment basin
111	19118630	4,838	Reservoir
112	19128629	2,419	Reservoir
113	06055765	*	Sediment basin
114	05685830	*	Sediment basin
115	05605790	*	
116	06585869	*	Sediment basin
117	05605635	*	
118	04555560	*	
119	04685545	*	
120	04755533	*	
121	06465855	*	
122	05036675	*	
123	05436890	*	
124	17906109	*	
125	17386174	*	
126	16806445	*	
127	12845820	*	
128	10485775	*	
129	10085685	*	
130	10905648	*	
131	11465558	*	
132	10705711	*	
133	05505877	*	
134	06055925	*	
135	22737359	*	
136	08546475	*	
137	10235810	*	
138	08126018	*	
139	07435805	*	
140	06075860	*	
141	06145733	*	
142	06425714	*	
143	04055493	*	
144	06095572	*	
145	06155464	*	
146	05915389	*	

* Water-surface area not determined (see paragraph 19).

Table 5

Heights of Debris Dams*

Maximum Height of Dam Aboveground Along Upstream Side of Structure, cm	
Dam 1	Dam 7
120	110
Dam 2	Dam 8
100	130
Dam 3	Dam 9
120	120
Dam 4	Dam 10
90	85
Dam 5	Dam 11
110	90
Dam 6	Dam 12
120	110

* For the locations of the debris dams, see Figure 14.

Table 6

Summary of Vegetation Data on Pitted Sites

Area No.	Sample Site Location (Military Coordinates)	Species Present (Common Name)	Percent Cover	Density	Frequency	Maximum Height cm	Average Height cm	Flowers or Fruits Present
2	10555485	Blue grama	28.0	1595	63.0	30.0	3.0	Yes
		Alkali sacaton	1.0	269	2.0	20.0	15.0	Yes
		Squirrel tail	1.0	403	2.0	12.0	10.0	Yes
		Russian thistle	14.0	164	74.0	15.0	4.0	Yes
3	07405935	Blue grama	22.0	758	53.0	40.0	4.0	Yes
		Russian thistle	13.0	77	68.0	11.0	2.0	No
4	06205790	Blue grama	18.0	856	54.0	28.0	7.0	Yes
		Alkali sacaton	1.0	14	1.0	23.0	7.0	Yes
		Squirrel tail	2.0	65	5.0	17.0	11.0	Yes
		Russian thistle	1.0	29	9.0	20.0	3.0	Yes
7	05005770	Indian ricegrass	5.7	147	9.7	54.0	13.3	Yes
		Squirrel tail	2.0	48	6.3	20.0	6.7	Yes
		Alkali sacaton	2.0	126	5.3	21.0	5.7	Yes
		Russian thistle	13.2	132	43.0	17.0	4.7	Yes
		Fetid marigold	0.3	1	1.7	6.0	2.0	No
		Scarlet mallow	0.2	1	0.7	4.0	1.3	No
8	04455725	Blue grama	41.0	836	73.4	36.0	8.6	Yes
		Squirrel tail	0.4	4	0.4	17.0	5.0	Yes
		Prickly pear	0.2	1	1.2	9.0	1.8	No
		Scarlet mallow	0.2	1	0.4	7.0	1.2	No
9	05805625	Squirrel tail	16.8	403	39.6	27.0	11.6	Yes
		Sand dropseed	2.6	21	11.2	54.0	9.2	Yes
		Three awn	8.2	246	23.6	25.0	11.4	Yes
		Russian thistle	0.2	2	1.8	7.0	0.8	No
		Unknown dicot	0.8	38	4.4	20.0	0.6	Yes
10	09255840	Blue grama	6.2	247	21.0	47.0	5.3	Yes
		Squirrel tail	2.0	40	4.3	18.0	4.0	Yes
		Alkali sacaton	0.3	9	1.3	19.0	1.3	No
		Stickleaf mentzelia	0.3	1	0.3	25.0	8.3	Yes
		Russian thistle	19.6	217	100.0	11.0	3.0	No
		Kochia	3.2	12	6.7	7.0	1.3	No
14	08006075	Blue grama	4.3	173	11.7	12.0	3.3	No
		Western wheatgrass	0.7	3	3.0	26.0	3.0	No
		Squirrel tail	0.3	8	0.3	21.0	5.0	Yes
		Russian thistle	24.0	192	73.7	12.0	3.7	No
		Kochia	0.3	2	1.3	4.0	0.7	No
		Scarlet mallow	3.0	7	10.7	11.0	3.7	No
		Sunflower	1.0	8	5.0	20.0	3.7	No
		Stickleaf mentzelia	0.3	1	0.7	9.0	2.3	No
15, 37	09006185	Blue grama	12.3	481	41.0	14.0	3.0	No
		Squirrel tail	1.0	22	2.3	14.0	3.3	Yes
		Ring muhly	0.3	18	1.7	--	--	--
		Russian thistle	7.2	160	36.7	9.0	3.0	No
		Kochia	4.3	12	14.3	5.0	0.7	No
		Prickly pear	0.3	1	0.3	7.0	2.3	No
		Scarlet mallow	0.3	1	2.0	7.0	1.3	No
16	07806260	Blue grama	8.3	325	25.3	19.0	7.7	No
		Ring muhly	1.3	73	5.0	17.0	2.3	Yes
		Alkali sacaton	0.7	25	1.7	30.0	5.7	Yes
		Kochia	28.5	241	50.0	24.0	6.3	No
		Plantain	0.5	4	3.0	17.0	7.0	Yes
		Russian thistle	0.1	2	2.7	6.0	3.7	No
		Scarlet mallow	1.7	3	6.7	5.0	1.3	No
		Wooly loco	0.3	1	1.3	5.0	1.7	No

(Continued)

Table 6 (Continued)

Area No.	Sample Site Location (Military Coordinates)	Species Present (Common Name)	Percent Cover	Density	Frequency	Maximum Height cm	Average Height cm	Flowers or Fruits Present
17	10006245	Blue grama	2.8	91	14.7	1.0	1.0	No
		Ring muhly	0.3	3	1.3	1.0	0.3	No
		Squirrel tail	0.3	4	1.3	9.0	2.7	Yes
		Plantain	1.6	2	13.3	6.0	1.7	Yes
		Kochia	0.1	1	0.7	3.0	0.7	No
18	08156535	Blue grama	8.0	344	27.3	6.0	3.0	No
		Ring muhly	1.3	58	3.0	7.0	3.0	Yes
		Russian thistle	1.9	42	19.7	5.0	3.0	No
		Scarlet mallow	0.3	1	2.3	4.0	4.0	No
		Kochia	56.7	417	80.3	12.0	5.3	No
19	07906620	Blue grama	33.3	1367	70.0	22.0	3.7	Yes
		Three awn	0.3	14	0.7	17.0	6.0	Yes
		Alkali sacaton	2.0	86	8.3	43.0	10.0	Yes
		Buckwheat	0.3	1	0.7	10.0	7.0	Yes
		Scarlet mallow	0.3	1	0.3	3.0	3.0	No
		Kochia	0.3	1	0.3	3.0	3.0	No
		Russian thistle	0.03	1	0.7	8.0	4.0	No
		Plantain	0.02	1	0.3	9.0	9.0	Yes
21	08956660	Blue grama	25.0	1525	62.7	23.0	3.3	Yes
		Squirrel tail	0.3	10	0.7	16.0	12.0	No
		Russian thistle	2.4	53	30.0	12.0	5.5	No
		Scarlet mallow	3.0	10	15.3	10.0	4.0	No
		Lambsquarter	0.3	1	0.3	23.0	23.0	Yes
		Plantain	0.1	2	1.7	12.0	8.3	Yes
		Unknown dicot	0.3	1	0.7	5.0	5.0	--
22	09906470	Blue grama	25.2	807	86.3	24.0	3.3	No
		Squirrel tail	0.3	1	1.3	12.0	10.0	Yes
		Ring muhly	1.7	93	8.0	3.0	1.5	No
		Alkali sacaton	1.0	28	3.7	12.0	6.0	No
		Plantain	1.2	27	23.3	13.0	2.7	Yes
		Scarlet mallow	0.3	1	0.7	4.0	3.0	No
		Russian thistle	0.2	3	2.3	6.0	4.0	No
23	09956295	Blue grama	14.2	640	70.3	11.0	2.0	No
		Ring muhly	1.0	15	4.7	2.0	0.7	No
		Three awn	0.3	29	2.7	8.0	2.0	No
		Plantain	1.2	28	19.7	11.0	6.3	Yes
		Wooly loco	0.3	1	2.3	5.0	4.0	No
		Russian thistle	0.2	4	4.3	12.0	2.3	No
		Scarlet mallow	2.0	8	8.3	8.0	4.3	No
		Alyssum	0.3	1	0.3	16.0	16.0	Yes
24	17406142	Blue grama	21.3	640	62.7	31.0	5.0	Yes
		Three awn	0.3	20	0.7	23.0	6.7	Yes
		Ring muhly	2.7	11	10.7	7.0	2.0	Yes
		Alkali sacaton	1.3	76	5.3	24.0	5.3	Yes
		Western wheatgrass	0.3	9	1.3	20.0	3.0	Yes
		Squirrel tail	1.0	34	3.3	18.0	10.0	Yes
		Russian thistle	0.8	19	9.7	21.0	4.7	No
		Unknown dicot	0.3	1	0.3	5.0	5.0	No
25	16406185	Blue grama	19.7	393	53.3	12.0	2.7	No
		Alkali sacaton	0.3	7	0.7	21.0	5.7	No
		Ring muhly	3.3	123	7.3	14.0	1.3	Yes
		Russian thistle	6.4	108	29.0	13.0	3.5	No
26	23256380	Alkali sacaton	1.6	67	4.2	30.0	5.6	Yes
		Squirrel tail	0.6	3	2.4	13.0	1.6	Yes
		Shadscale	18.6	1	27.6	30.0	10.8	No
		Prickly pear	0.4	1	1.8	8.0	2.2	No
		Russian thistle	3.8	76	9.4	5.0	1.8	No
		Broom snakeweed	0.2	6	0.6	1.0	0.2	No
		Gaillardia	0.2	1	0.6	17.0	1.4	Yes
		Frankenia	0.2	3	1.2	3.0	0.6	No

(Continued)

Table 6 (Concluded)

Area No.	Sample Site Location (Military Coordinates)	Species Present (Common Name)	Percent Cover	Density	Frequency	Maximum Height cm	Average Height cm	Flowers or Fruits Present
31	15805395	Three awn	0.3	5	0.7	19.0	3.7	Yes
		Alkali sacaton	3.3	49	7.3	35.0	6.0	Yes
		Squirrel tail	0.8	23	3.0	27.0	6.3	Yes
		Western wheatgrass	0.3	9	1.0	22.0	3.0	No
		Scarlet mallow	0.8	3	7.3	13.0	6.3	Yes
		Russian thistle	4.9	109	28.7	24.0	6.3	Yes
33	05806900	Blue grama	21.3	896	57.0	36.0	6.3	Yes
		Squirrel tail	2.3	47	8.0	24.0	9.0	Yes
		Tumblegrass	0.5	24	1.3	17.0	2.7	Yes
		Ring muhly	0.7	25	2.0	17.0	1.0	Yes
		Plantain	9.2	54	93.7	12.0	9.5	Yes
		Helinium	1.3	1	2.7	48.0	16.0	Yes
		Russian thistle	0.9	19	10.0	17.0	5.7	No
		Kochia	0.3	1	0.7	15.0	5.0	No
34	06857005	Blue grama	13.0	585	63.7	30.0	3.3	Yes
		Ring muhly	3.7	203	10.3	17.0	2.7	Yes
		Three awn	1.3	77	3.3	16.0	3.3	Yes
		Stickleaf mentzelia	0.3	1	0.3	8.0	8.0	No
		Plantain	0.6	7	6.7	13.0	4.3	Yes
		Fetid marigold	0.3	51	5.0	7.0	2.7	Yes
		Kochia	2.8	13	11.3	20.0	8.7	Yes
		Prince's plume	0.3	2	1.3	31.0	5.3	Yes
		Russian thistle	1.0	16	3.3	17.0	5.0	Yes
		Frankenia	1.7	1	4.0	16.0	3.3	Yes
		Mamillaria	0.3	1	0.3	2.0	0.3	No
		Unknown dicot	1.0	2	2.0	9.0	5.7	Yes
35	07357030	Blue grama	0.3	22	0.7	5.0	1.3	No
		Alkali sacaton	4.5	52	10.3	34.0	11.7	Yes
		Three awn	4.2	175	12.7	26.0	5.3	Yes
		Sleepy grass	3.3	113	4.3	74.0	10.0	Yes
		Kochia	16.4	113	31.7	25.0	4.7	Yes
		Russian thistle	42.2	430	95.0	18.0	6.7	No
		Fetid marigold	0.4	12	2.0	7.0	1.3	No
		Alyssum	1.7	4	17.7	60.0	17.3	Yes
		Blue flax	1.0	1	3.3	27.0	8.3	Yes
		Unknown dicot	0.3	1	0.3	28.1	8.0	No
38	05806580	Blue grama	11.3	397	33.7	34.0	5.3	Yes
		Alkali sacaton	0.3	8	0.7	26.0	3.3	No
		Squirrel tail	0.3	6	1.0	15.0	3.0	Yes
		Russian thistle	11.3	251	43.3	24.0	6.0	Yes
		Frankenia	0.3	1	1.3	3.0	0.7	Yes
		Lambsquarter	0.3	1	0.3	4.0	1.3	Yes
		Scarlet mallow	0.3	1	0.3	3.0	0.7	No
		Plantain	0.2	5	0.7	15.0	3.0	Yes
39	08656530	Blue grama	17.7	336	66.3	30.0	3.0	Yes
		Ring muhly	2.3	40	9.7	12.0	1.3	Yes
		Alkali sacaton	1.3	8	3.0	36.0	7.7	Yes
		Squirrel tail	0.3	3	0.7	12.0	1.7	Yes
		Three awn	0.3	4	0.3	11.0	2.7	Yes
		Scarlet mallow	0.3	2	1.3	7.0	1.7	No
		Russian thistle	3.5	79	25.7	16.0	2.7	Yes
40	08805745	Blue grama	14.0	602	39.3	21.0	4.7	Yes
		Squirrel tail	4.0	60	15.0	16.0	5.3	Yes
		Russian thistle	12.9	69	76.7	14.0	3.3	Yes

Table 7

Summary of Vegetative Data on Pitted and Seeded Sites

Area No.	Sample Site Location (Military Coordinates)	Species Present (Common Name)	Percent Cover	Density	Frequency	Maximum Height cm	Average Height cm	Flowers or Fruits Present
1	10555415	Blue grama	22.0	975	46.0	33.0	4.0	Yes
		Russian thistle	13.0	95	65.0	28.0	7.0	Yes
5	06005900	Russian wildrye	3.7	216	14.0	18.0	3.0	Yes
		Squirrel tail	0.3	15	0.3	28.0	4.3	Yes
		Wheatgrass crested	10.3	315	26.3	55.0	11.3	Yes
		Russian thistle	15.7	82	27.7	8.0	3.7	No
		Scarlet mallow	0.7	2	4.3	8.0	4.0	No
6	05475865	Alkali sacaton	5.0	189	16.7	45.0	8.3	Yes
		Squirrel tail	5.3	101	14.3	17.0	6.7	Yes
		Three awn	2.7	106	6.0	13.0	6.0	No
		Russian thistle	27.0	163	96.7	15.0	9.0	Yes
		Unknown dicot	1.0	16	5.3	7.0	1.7	Yes
7	04755755	Blue grama	34.7	1248	68.7	34.0	8.3	Yes
		Ring muhly	2.0	68	7.3	7.0	1.7	No
		Squirrel tail	1.3	33	6.0	14.0	8.3	Yes
		Russian thistle	3.1	12	26.3	7.0	2.7	No
		Scarlet mallow	0.3	1	1.3	5.0	1.0	No
10	09355846	Blue grama	4.3	184	17.0	8.0	2.0	No
		Crested wheatgrass	5.3	176	17.0	43.0	3.3	Yes
		Squirrel tail	0.3	5	1.3	14.0	2.3	Yes
		Mamillaria	0.3	1	0.3	2.0	0.7	No
		Russian thistle	19.3	162	61.0	4.0	2.0	No
15	08406225	Three awn	0.3	14	1.0	8.0	1.3	No
		Alkali sacaton	0.7	19	3.3	14.0	3.0	Yes
		Tumblegrass	0.7	3	1.0	6.0	3.0	No
		Squirrel tail	0.3	1	1.7	9.0	2.3	Yes
		Scarlet mallow	3.3	14	20.3	10.0	4.0	Yes
		Russian thistle	14.8	95	95.0	8.0	3.0	No
		Gaillardia	0.3	1	1.7	9.0	3.0	Yes
		Sunflower	0.3	1	0.7	6.0	2.0	No
		Unknown dicot	0.7	1	2.0	9.0	3.0	Yes
17	10006185	Blue grama	25.0	1000	85.0	30.0	1.7	No
		Ring muhly	0.7	19	3.7	2.0	0.7	No
		Russian thistle	11.0	85	43.0	4.0	1.3	No
		Scarlet mallow	0.3	1	0.7	3.0	1.0	No
		Plantain	0.2	4	3.7	5.0	1.3	Yes
19	08056675	Blue grama	37.7	1025	73.0	30.0	5.0	Yes
		Alkali sacaton	1.0	36	4.7	32.0	14.0	Yes
		Three awn	2.0	176	5.3	22.0	13.0	Yes
		Helinium	3.3	3	10.7	26.0	22.0	Yes
		Blue flax	0.7	1	2.7	15.0	12.0	No
		Scarlet mallow	0.7	2	1.7	3.0	3.0	No
		Plantain	0.7	8	3.3	12.0	7.0	Yes
20	08506690	Blue grama	39.7	1587	81.3	32.0	4.7	Yes
		Squirrel tail	1.7	50	7.0	19.0	14.0	Yes
		Alkali sacaton	0.3	3	0.3	41.0	7.0	Yes
		Russian thistle	0.8	17	21.3	5.0	2.0	No
		Kochia	0.3	1	0.7	3.0	3.0	Yes
22	09506510	Blue grama	30.1	1235	87.0	37.0	5.0	Yes
		Alkali sacaton	1.3	21	5.3	42.0	4.7	Yes
		Squirrel tail	0.7	11	2.0	23.0	8.3	Yes
		Three awn	0.3	12	0.7	11.0	10.0	Yes
		Ring muhly	0.3	11	1.3	2.0	2.0	No
		Russian thistle	0.2	4	1.7	4.0	3.0	No
		Plantain	3.1	70	36.0	13.0	8.7	Yes
		Helinium	0.3	1	0.3	5.0	5.0	No
		Kochia	0.3	1	0.3	3.0	3.0	No

(Continued)

Table 7 (Concluded)

Area No.	Sample Site Location (Military Coordinates)	Species Present (Common Name)	Percent Cover	Density	Frequency	Maximum Height cm	Average Height cm	Flowers or Fruits Present
26	23506400	Blue grama	13.4	507	23.2	57.0	8.4	Yes
		Wheatgrass	0.4	3	1.6	50.0	11.8	Yes
		Sand dropseed	0.8	6	2.8	25.0	3.6	No
		Shadscale	4.4	1	9.0	25.0	4.6	No
		Frankenia	10.2	2	15.0	24.0	8.2	No
		Gaillardia	0.8	2	2.2	14.0	3.7	Yes
		Scarlet mallow	1.0	1	2.8	13.0	5.0	No
		Bigelow sage	0.6	1	1.8	22.0	3.2	No
		Broom snakeweed	0.2	1	0.2	2.0	0.4	No
		Russian thistle	0.2	6	1.8	3.0	0.2	No
27	19456455	Wheatgrass	0.2	1	0.2	7.0	7.0	No
		Gaillardia	6.1	5	17.2	17.0	7.6	Yes
		Scarlet mallow	0.4	1	2.0	7.0	2.2	Yes
		Broom snakeweed	2.9	35	23.4	19.0	6.8	Yes
		Shadscale	2.2	1	4.0	19.0	3.2	No
		Frankenia	0.5	1	1.0	14.0	2.4	No
28	17056450	Indian ricegrass	8.8	35	26.8	54.0	18.0	Yes
		Plantain	0.2	1	0.2	36.0	36.0	Yes
		Gaillardia	1.8	3	7.4	17.0	8.2	No
		Bigelow sage	1.4	1	3.2	21.0	4.8	No
		Frankenia	2.4	1	4.0	15.0	3.0	No
		Gumweed	0.2	1	0.6	14.0	2.8	Yes
		Scarlet mallow	0.2	1	0.2	4.0	0.8	No
		Unknown dicot	0.4	1	0.4	10.0	2.6	No
32	06256940	Three awn	11.3	680	40.3	30.0	12.7	Yes
		Tumblegrass	0.7	19	3.3	24.0	3.3	Yes
		Crested wheatgrass	16.7	317	45.0	48.0	20.7	Yes
		Frankenia	0.5	1	1.3	17.0	5.0	Yes
		Alyssum	0.3	1	3.0	33.0	5.3	Yes
		Unknown dicot	0.3	1	1.3	33.0	6.0	Yes
37	08706160	Blue grama	4.7	145	23.3	18.0	1.7	No
		Squirrel tail	1.2	35	4.7	18.0	4.0	Yes
		Russian thistle	26.1	177	90.0	8.0	3.3	No
		Cholla	0.3	1	0.7	2.0	0.7	No

Table 8

Summary of Vegetation Data on Ripped Sites

Area No.	Sample Site Location (Military Coordinates)	Species Present (Common Name)	Percent Cover	Density	Frequency	Maximum Height cm	Average Height cm	Flowers or Fruits Present
29	15235423	Crested wheatgrass	5.7	227	11.0	55.0	4.4	Yes
		Three awn	0.7	27	2.3	27.0	3.7	Yes
		Russian wildrye	0.3	1	0.3	6.0	1.3	No
		Frankenia	1.0	1	2.2	16.0	3.7	Yes
		Buckwheat	0.3	1	1.0	6.0	1.7	Yes
		Russian thistle	16.2	60	38.3	36.0	6.3	Yes
		Bitterweed	0.3	1	0.3	22.0	3.2	Yes
		Unknown dicot	1.3	1	2.6	20.0	3.3	Yes
30	15605406	Blue grama	4.8	97	15.0	41.0	7.7	Yes
		Squirrel tail	1.0	24	3.3	20.0	14.0	Yes
		Alkali sacaton	0.7	23	6.0	50.0	4.3	No
		Russian thistle	4.5	193	27.0	23.0	5.3	Yes
		Scarlet mallow	1.5	6	8.3	11.0	5.3	No
		Unknown dicot #1	5.3	45	9.0	15.0	3.3	Yes
		Unknown dicot #2	0.3	1	1.3	12.0	2.3	No

Table 9

Summary of Vegetation Data on Untreated Sites

Area No.	Sample Site Location (Military Coordinates)	Species Present (Common Name)	Percent Cover	Density	Frequency	Maximum Height cm	Average Height cm	Flowers or Fruits Present
1, 2	10555350	Blue grama	34.0	1648	88.0	7.0	3.0	Yes
		Russian thistle	5.0	35	100.0	11.0	4.0	Yes
3	07405935	Blue grama	16.0	566	60.0	18.0	4.0	No
		Squirrel tail	1.0	1	1.0	10.0	4.0	Yes
		Russian thistle	20.0	106	79.0	7.0	2.0	No
4, 5, 6	06255865	Blue grama	20.0	880	59.0	12.0	5.0	Yes
		Squirrel tail	2.3	79	5.3	18.0	7.0	Yes
		Three awn	0.3	2	0.7	10.0	3.0	No
		Winter fat	1.0	1	1.3	17.0	4.7	No
		Russian thistle	19.2	90	70.3	12.0	4.0	No
		Scarlet mallow	1.0	3	5.7	7.0	2.0	No
7	04855770	Blue grama	0.3	13	0.3	3.0	0.7	No
		Three awn	0.3	1	0.3	9.0	3.0	Yes
		Squirrel tail	1.0	32	2.7	20.0	9.7	Yes
		Western wheatgrass	4.3	156	18.7	32.0	9.7	Yes
		Vetch	2.3	4	5.3	14.0	10.3	No
		Russian thistle	7.5	19	63.0	7.0	3.3	No
		Scarlet mallow	1.7	5	10.7	15.0	6.7	No
8	04265710	Blue grama	23.6	378	41.4	50.0	15.7	Yes
		Ring muhly	9.6	476	18.2	9.0	2.6	Yes
		Squirrel tail	1.3	41	13.3	18.0	11.3	Yes
		Sand dropseed	4.2	126	9.6	39.0	7.4	Yes
		Prickly pear	1.3	1	5.7	15.0	2.8	Yes
		Russian thistle	0.2	1	1.7	9.0	1.4	No
		Mamillaria	0.2	1	0.2	2.0	0.4	No
9	05655600	Squirrel tail	8.3	212	18.7	30.0	15.3	Yes
		Sand dropseed	2.0	31	4.7	54.0	7.3	Yes
		Three awn	0.7	30	1.7	13.0	3.3	Yes
		Russian thistle	10.1	416	100.0	15.0	4.3	Yes
		Plantain	0.7	1	1.7	10.0	5.0	Yes
		Scarlet mallow	1.3	10	9.0	13.0	7.0	No
		Unknown dicot	0.3	1	1.3	14.0	2.7	Yes
10, 40	08955750	Squirrel tail	9.7	145	30.3	22.0	13.3	Yes
		Alkali sacaton	7.0	182	28.0	50.0	6.3	Yes
		Blue grama	2.3	93	6.7	44.0	4.7	Yes
		Russian thistle	2.5	57	23.3	13.0	1.0	No
		Scarlet mallow	2.0	5	10.3	8.0	3.3	No
14	07906100	Blue grama	4.3	160	21.0	11.0	2.3	No
		Squirrel tail	4.0	96	12.3	26.0	8.3	Yes
		Russian thistle	1.4	11	31.0	3.0	0.7	No
		Plantain	0.3	1	0.3	6.0	2.0	Yes
		Kochia	37.1	167	61.0	3.0	1.0	No
15, 37	09006185	Blue grama	26.9	1345	78.3	15.0	2.7	No
		Ring muhly	1.3	57	3.0	4.0	2.0	No
		Squirrel tail	0.7	17	4.0	16.0	3.3	Yes
		Russian thistle	2.7	60	21.7	4.0	1.3	No
		Scarlet mallow	0.3	1	0.7	6.0	1.0	No
16	07806260	Squirrel tail	1.0	22	2.7	18.6	4.0	Yes
		Three awn	0.3	12	0.3	16.0	2.3	Yes
		Blue grama	21.5	860	93.0	13.0	5.3	Yes
		Alkali sacaton	0.3	1	0.3	35.0	11.7	Yes
		Scarlet mallow	0.7	1	3.0	7.0	3.3	Yes
		Plantain	3.7	17	28.3	19.0	5.3	Yes
		Kochia	0.03	1	0.3	3.0	1.0	No

(Continued)

Table 9 (Continued)

Area No.	Sample Site Location (Military Coordinates)	Species Present (Common Name)	Percent Cover	Density	Frequency	Maximum Height cm	Average Height cm	Flowers or Fruits Present
17, 23	09906275	Blue grama	15.5	697	78.3	17.0	2.3	No
		Three awn	0.7	30	4.7	13.0	2.0	Yes
		Alkali sacaton	2.0	44	14.0	21.0	1.0	Yes
		Wooly loco	0.7	1	1.0	6.0	3.3	Yes
		Scarlet mallow	1.3	3	8.0	7.0	4.7	No
		Plantain	0.6	12	14.3	10.0	6.3	Yes
		Frankenia	0.3	1	0.7	9.0	3.0	No
		Russian thistle	0.03	1	2.0	6.0	1.3	No
		Alyssum	0.3	1	1.3	15.0	1.7	Yes
18, 39	10866555	Blue grama	38.3	2185	96.0	22.0	3.0	Yes
		Alkali sacaton	0.3	6	2.7	12.0	0.7	Yes
		Russian thistle	2.4	51	19.0	9.0	2.0	No
19, 20	08406637	Blue grama	29.0	696	100.0	16.0	1.7	Yes
		Ring muhly	0.3	16	0.3	1.0	0.3	No
		Alkali sacaton	0.3	8	0.3	--	--	--
		Three awn	0.3	3	0.7	--	--	--
21	08956630	Blue grama	31.2	1215	74.7	20.0	4.0	Yes
		Squirrel tail	4.7	107	10.0	19.0	6.7	Yes
		Alkali sacaton	4.0	136	11.3	40.0	6.7	Yes
		Ring muhly	0.7	29	3.0	2.0	0.7	No
		Plantain	0.03	1	0.7	6.0	3.7	Yes
22	09906460	Blue grama	33.0	1056	100.0	21.0	3.0	No
		Alkali sacaton	1.3	31	4.0	19.0	2.7	No
		Ring muhly	0.3	19	0.3	1.0	0.3	No
		Three awn	0.3	20	1.0	16.0	3.3	Yes
		Plantain	0.4	9	7.3	11.0	5.3	Yes
		Barrel cactus	0.7	1	1.3	2.0	1.0	No
		Frankenia	0.3	1	1.3	4.0	1.3	Yes
		Blue flax	0.3	1	0.7	26.0	8.7	No
		Bitterweed	0.3	1	0.3	3.0	1.0	No
24, 25	16906130	Blue grama	40.7	976	90.3	7.0	3.0	No
		Ring muhly	1.3	58	4.0	3.0	0.7	No
		Winterfat	1.0	1	3.0	17.0	5.3	No
		Scarlet mallow	0.3	2	1.7	6.0	1.0	No
		Russian thistle	0.07	2	2.3	5.0	1.0	No
26	24106400	Alkali sacaton	1.0	27	2.0	32.0	3.6	No
		Galleta	3.4	48	6.0	46.0	2.4	Yes
		Shadscale	20.8	3	30.0	23.0	13.2	No
27	20756445	Sand dropseed	0.5	9	1.3	24.0	2.7	Yes
		Wheatgrass	0.7	6	5.7	29.0	11.7	Yes
		Frankenia	17.7	4	35.7	21.0	8.3	No
		Shadscale	7.5	2	15.7	19.0	12.3	No
		Gaillardia	0.5	1	1.7	8.0	2.3	Yes
28	16806515	Blue grama	25.0	750	56.2	14.0	4.7	Yes
		Three awn	3.5	52	11.0	20.0	3.2	Yes
		Squirrel tail	0.2	2	1.0	10.0	2.2	Yes
		Bigelow sage	2.0	1	4.7	19.0	10.2	No
		Scarlet mallow	2.0	7	9.7	7.0	3.2	No
		Broom snakeweed	0.5	7	3.7	2.0	0.5	No

(Continued)

Table 9 (Concluded)

Area No.	Sample Site Location (Military Coordinates)	Species Present (Common Name)	Percent Cover	Density	Frequency	Maximum Height cm	Average Height cm	Flowers or Fruits Present
29	15235425	Blue grama	22.7	907	55.3	14.0	3.3	Yes
		Alkali sacaton	0.7	20	2.3	19.0	3.7	Yes
		Three awn	1.0	39	2.7	20.0	3.0	Yes
		Russian thistle	2.4	25	11.3	13.0	2.3	No
		Scarlet mallow	0.3	1	1.0	2.0	0.7	No
		Soapweed	3.7	1	6.3	26.0	8.0	No
		Frankenia	1.0	1	3.3	14.0	4.0	No
		Winterfat	0.3	1	1.0	23.0	6.3	Yes
		Unknown dicot	0.7	1	1.7	9.0	2.0	Yes
30, 31	15705420	Blue grama	0.3	11	1.3	7.0	1.7	Yes
		Squirrel tail	2.0	42	6.7	19.0	13.0	Yes
		Three awn	3.8	161	12.3	25.0	16.0	Yes
		Alkali sacaton	1.2	8	7.0	12.0	4.0	No
		Western wheatgrass	0.3	7	1.3	6.0	1.0	Yes
		Scratch muhly	1.0	30	2.7	11.0	1.7	Yes
		Russian thistle	1.8	40	35.3	10.0	2.0	Yes
		Scarlet mallow	0.8	2	5.7	7.0	1.7	No
		Sunflower	0.3	1	0.3	10.0	3.3	Yes
		Blue flax	0.3	1	0.3	11.0	3.3	Yes
		Unknown dicot	0.7	10	5.0	21.0	4.7	Yes
32	06626900	Blue grama	26.5	1298	88.3	34.0	4.0	Yes
		Alkali sacaton	0.7	23	2.0	33.0	3.7	Yes
		Three awn	0.7	27	1.0	16.0	1.7	Yes
		Bitterweed	1.0	3	2.3	49.0	2.7	Yes
		Plantain	0.2	4	4.0	8.0	2.0	Yes
		Haplopappus	3.7	2	11.0	15.0	7.3	Yes
		Daisy fleabane	0.3	1	0.3	10.0	3.3	Yes
		Fetid marigold	0.7	1	0.7	12.0	4.7	Yes
		Kochia	0.3	1	0.7	10.0	1.3	No
33	06306895	Blue grama	40.3	1654	98.7	31.0	3.0	Yes
		Scarlet mallow	0.3	1	1.7	4.0	1.0	No
		Plantain	3.7	22	31.0	8.0	3.3	Yes
		Fetid marigold	0.3	1	0.7	7.0	2.3	No
		Liatris	0.3	1	0.7	11.0	3.7	No
		Prince's plume	1.0	1	2.7	23.0	7.3	No
		Mamillaria	0.7	1	2.0	1.0	0.3	No
		Haplopappus	0.3	1	0.3	15.0	3.0	Yes
		Blue flax	1.0	1	4.0	--	--	--
34, 35	07307055	Blue grama	5.3	341	20.7	36.0	9.7	Yes
		Alkali sacaton	27.7	941	47.7	84.0	26.7	Yes
		Tumblegrass	2.7	184	11.0	17.0	4.7	Yes
		Three awn	5.0	325	9.0	23.0	5.3	Yes
		Sleepygrass	1.3	44	2.0	102.0	10.3	Yes
		Indian ricegrass	2.0	62	7.0	30.0	10.0	Yes
		Bitterweed	0.3	1	0.7	23.0	7.7	No
		Alyssum	2.0	2	6.3	60.0	16.7	Yes
		Clover	3.7	1	7.7	37.0	6.3	No
		Bindweed	0.7	3	2.7	30.0	5.3	No
38	06006585	Three awn	13.7	711	28.7	28.0	11.7	Yes
		Ring muhly	14.7	880	52.0	17.0	3.0	Yes
		Scarlet mallow	1.0	3	4.0	10.0	3.7	No
		Russian thistle	0.9	21	4.3	20.0	4.0	Yes
		Verbena	5.8	30	10.3	13.0	2.7	Yes
		Frankenia	4.7	14	5.3	10.0	3.0	Yes

Table 10

Scientific Names of Plants Occurring in Sample Sites

Species No.	Common Name*	Scientific Name**	Grass or Nongrass†
1	Alkali sacaton	Sporobolus airoides	G
2	Aster	Aster sp.	O
3	Barrel cactus	Echinocactus sp.	O
4	Bigelow sage	Artemisia bigelovii	O
5	Bindweed	Convolvulus arvensis	O
6	Bitterweed	Helinium sp.	O
7	Blue flax	Linum lewisii	O
8	Blue grama	Bouteloua gracilis	G
9	Broom snakeweed	Gutierrezia sarothrae	O
10	Buckwheat	Eriogonum sp.	O
11	Cholla	Opuntia arborescens	O
12	Clover	Melilotus sp.	O
13	Crested wheatgrass	Agropyron cristatum	G
14	Daisy fleabane	Erigeronstrigosus	O
15	Fetid marigold	Dyssodia papposa	O
16	Frankenia	Frankenia jamesii	O
17	Gaillardia	Gaillardia pulchella	O
18	Galleta	Hilaria jamesii	G
19	Gumweed	Grindelia squarrosa	O
20	Haplopappus	Haplopappus sp.	O
21	Helinium	Helinium sp.	O
22	Indian ricegrass	Oryzopsis hymenoides	G
23	Kochia	Kochia scoparia	O
24	Lambsquarter	Chenopodium album	O
25	Liatris	Liatris punctata	O
26	Mamillaria	Mamillaria sp.	O
27	Alyssum	Alyssum alyssoides	O
28	Plantain	Plantago purshii	O
29	Prickly pear	Opuntia polyacantha	O
30	Prince's plume	Stanleya pinnata	O
31	Ring muhly	Muhlenbergia torreyi	G
32	Russian thistle	Salsola kali	O
33	Russian wildrye	Elymus junceus	O
34	Sand dropseed	Sporobolus cryptandrus	G
35	Scarlet mallow	Sphaeralcea coccinea	G
36	Scratchgrass muhly	Muhlenbergia asperifolia	O
37	Shadscale	Atriplex confertifolia	G
38	Sleepy needlegrass	Stipa robusta	O
39	Soap weed	Yucca glauca	G
40	Squirrel tail	Sitanion hystrix	O
41	Stickleaf mentzelia	Mentzelia oligosperma	O
42	Sunflower	Helianthus annuus	O
43	Three awn	Aristida longiseta	G
44	Tumblegrass	Schedonnardus paniculatus	G
45	Verbena	Verbena sp.	O
46	Vetch	Vicia sp.	O
47	Western wheatgrass	Agropyron smithii	G
48	Winterfat	Eurotia lanata	O
49	Wooly loco	Oxytropis sp.	O

* From H. D. Harrington (1964)[16], A. S. Hitchcock (1950)[17], or communicated by Edward C. Dennis (USDA-SCS, La Junta, Colo.) in September 1975.

** From H. D. Harrington (1964).

† G = members of the family Gramineae; O = members of any other plant family than the grasses.

Table 11

Percent Vegetation Cover in Untreated and Treated Areas

Area No. a	Untreated b	Pitted c	Difference Between Pitted and Untreated* d	Pitted and Seeded e	Difference Between Pitted and Seeded and Untreated* f	Ripped g	Difference Between Ripped and Untreated* h
1	39.0	--	--	35.0	-4.0	--	--
2	39.0	44.0	+5.0	--	--	--	--
3	37.0	35.0	-2.0	--	--	--	--
4	43.8	22.0	-21.8	--	--	--	--
5	43.8	--	--	30.7	-13.1	--	--
6	43.8	--	--	41.0	-2.8	--	--
7	17.4	23.4	+6.0	41.4	+24.0	--	--
8	40.4	41.8	+1.4	--	--	--	--
9	23.4	28.6	+5.2	--	--	--	--
10	23.5	31.6	+8.1	29.5	+6.0	--	--
11**	--	--	--	--	--	--	--
12**	--	--	--	--	--	--	--
13**	--	--	--	--	--	--	--
14	47.1	33.9	-14.2	--	--	--	--
15	31.9	25.7	-6.2	21.4	-10.5	--	--
16	27.5	41.4	+13.9	--	--	--	--
17	21.4	5.1	-16.3	37.2	+15.8	--	--
18	41.0	68.2	+27.2	--	--	--	--
19	29.9	36.6	+6.7	46.0	+16.1	--	--
20	29.9	--	--	42.8	+12.9	--	--
21	40.6	31.4	-9.2	--	--	--	--
22	36.9	29.0	-7.0	36.6	-0.3	--	--
23	21.4	19.5	-1.9	--	--	--	--
24	43.4	28.0	-15.4	--	--	--	--
25	43.4	29.7	-13.7	--	--	--	--
26	25.2	25.6	+0.4	32.0	+6.8	--	--
27	26.9	--	--	12.3	-14.6	--	--
28	33.2	--	--	15.4	-17.8	--	--
29	32.8	--	--	--	--	25.8	-7.0
30	12.5	--	--	--	--	18.1	+5.6
31	12.5	10.4	+2.1	--	--	--	--
32	34.1	--	--	29.8	-4.3	--	--
33	47.9	36.5	-11.4	--	--	--	--
34	50.7	26.3	-24.4	--	--	--	--
35	50.7	74.3	+23.6	--	--	--	--
36**	--	--	--	--	--	--	--
37	31.9	25.7	-6.2	32.3	+0.4	--	--
38	40.8	24.3	-16.5	--	--	--	--
39	41.0	25.7	-15.3	--	--	--	--
40	23.5	30.9	+7.4	--	--	--	--
41**	--	--	--	--	--	--	--
Average	34.7	31.7	-2.7	32.2	-1.0	22.0	-0.7

* A + means greater percent vegetation cover in the treated area than in the untreated area. A - means less percent vegetation cover in the treated area than in the untreated area.

** Not sampled.

Table 12

Percent Grass Cover in Untreated and Treated Areas

Area No. a	Untreated b	Pitted c	Difference Between Pitted and Untreated* d	Pitted and Seeded e	Difference Between Pitted and Seeded and Untreated* f	Ripped g	Difference Between Ripped and Untreated* h
1	34.0	--	--	22.0	-12.0	--	--
2	34.0	30.0	-4.0	--	--	--	--
3	17.0	22.0	+5.0	--	--	--	--
4	22.6	21.0	-1.6	--	--	--	--
5	22.6	--	--	14.3	-8.3	--	--
6	22.6	--	--	13.0	-9.6	--	--
7	5.9	9.7	+3.8	38.0	+32.1	--	--
8	38.7	41.4	+2.7	--	--	--	--
9	11.0	27.6	+16.6	--	--	--	--
10	19.0	8.5	-10.5	9.9	-9.1	--	--
11**	--	--	--	--	--	--	--
12**	--	--	--	--	--	--	--
13**	--	--	--	--	--	--	--
14	8.3	5.3	-3.0	--	--	--	--
15	28.9	13.6	-15.3	2.0	-26.9	--	--
16	23.1	10.3	-12.8	--	--	--	--
17	18.2	3.4	-14.8	25.7	+7.5	--	--
18	38.6	9.3	-29.3	--	--	--	--
19	29.9	35.6	+5.7	40.7	+10.8	--	--
20	29.9	--	--	41.7	+11.8	--	--
21	40.6	25.3	-15.3	--	--	--	--
22	34.9	28.2	-6.7	32.7	-2.2	--	--
23	18.2	15.5	-2.7	--	--	--	--
24	42.0	26.9	-15.1	--	--	--	--
25	42.0	23.3	-18.7	--	--	--	--
26	4.4	2.2	-2.2	14.6	+10.2	--	--
27	1.2	--	--	0.2	-1.0	--	--
28	28.7	--	--	8.8	-19.9	--	--
29	24.4	--	--	--	--	6.7	-17.7
30	8.6	--	--	--	--	6.5	-2.1
31	8.6	4.7	-3.9	--	--	--	--
32	27.9	--	--	28.7	+0.8	--	--
33	40.3	24.8	-15.5	--	--	--	--
34	44.0	18.0	-26.0	--	--	--	--
35	44.0	12.3	-31.7	--	--	--	--
36**	--	--	--	--	--	--	--
37	28.9	13.6	-15.3	5.9	-23.0	--	--
38	28.4	11.9	-16.5	--	--	--	--
39	38.6	21.9	-16.7	--	--	--	--
40	19.0	18.0	-1.0	--	--	--	--
41**	--	--	--	--	--	--	--
Average	25.8	17.9	-9.7	19.9	-2.6	6.6	-9.9

* A + means greater percent grass cover in the treated area than in the untreated area. A - means less percent grass cover in the treated area than in the untreated area.

** Not sampled.

Table 13

Vegetation Density (Plants/m^2) in Untreated and Treated Areas

Area No. a	Untreated b	Pitted c	Difference Between Pitted and Untreated* d	Pitted and Seeded e	Difference Between Pitted and Seeded and Untreated* f	Ripped g	Difference Between Ripped and Untreated* h
1	1683	--	--	1070	-613	--	--
2	1683	2431	+748	--	--	--	--
3	673	835	+162	--	--	--	--
4	1055	964	-91	--	--	--	--
5	1055	--	--	630	-425	--	--
6	1055	--	--	575	-480	--	--
7	230	455	+225	1362	+1132	--	--
8	1024	842	-182	--	--	--	--
9	701	710	+9	--	--	--	--
10	482	526	+44	528	+46	--	--
11**	--	--	--	--	--	--	--
12**	--	--	--	--	--	--	--
13**	--	--	--	--	--	--	--
14	435	394	-41	--	--	--	--
15	1480	695	-785	147	-548	--	--
16	914	674	-240	--	--	--	--
17	790	101	-689	1109	+319	--	--
18	2242	862	-1380	--	--	--	--
19	723	1472	+749	1251	+528	--	--
20	723	--	--	1658	+935	--	--
21	1488	1602	+114	--	--	--	--
22	1139	960	-179	1366	+227	--	--
23	790	726	-64	--	--	--	--
24	1039	810	-229	--	--	--	--
25	1039	631	-408	--	--	--	--
26	78	158	+80	530	+452	--	--
27	22	--	--	44	+22	--	--
28	819	--	--	44	-775	--	--
29	996	--	--	--	--	314	-680
30	313	--	--	--	--	389	+76
31	313	198	-115	--	--	--	--
32	1360	--	--	1019	-341	--	--
33	1683	1067	-616	--	--	--	--
34	1904	959	-945	--	--	--	--
35	1904	923	-981	--	--	--	--
36**	--	--	--	--	--	--	--
37	1480	695	-785	358	-1122	--	--
38	1659	670	-989	--	--	--	--
39	2242	472	-1770	--	--	--	--
40	482	731	+249	--	--	--	--
41**	--	--	--	--	--	--	--
Average	1047	799	-300	779	-43	352	-302

* A + means greater vegetation density in the treated area than in the untreated area.
A - means less vegetation density in the treated area than in the untreated area.
** Not sampled.

Table 14

Grass Density ($Plants/m^2$) in Untreated and Treated Areas

Area No. a	Untreated b	Pitted c	Difference Between Pitted and Untreated* d	Pitted and Seeded e	Difference Between Pitted and Seeded and Untreated* f	Ripped g	Difference Between Ripped and Untreated* h
1	1648	--	--	975	-673	--	--
2	1648	2267	+619	--	--	--	--
3	567	758	+191	--	--	--	--
4	961	935	-26	--	--	--	--
5	961	--	--	546	-415	--	--
6	961	--	--	396	-565	--	--
7	202	321	+119	1349	+1147	--	--
8	1021	840	-181	--	--	--	--
9	273	670	+397	--	--	--	--
10	420	296	-124	365	-55	--	--
11**	--	--	--	--	--	--	--
12**	--	--	--	--	--	--	--
13**	--	--	--	--	--	--	--
14	256	184	-72	--	--	--	--
15	1419	521	-898	37	-1382	--	--
16	895	423	-472	--	--	--	--
17	771	98	-673	1019	+248	--	--
18	2191	402	-1789	--	--	--	--
19	723	1467	+744	1237	+514	--	--
20	723	--	--	1640	+917	--	--
21	1487	1535	+48	--	--	--	--
22	1126	929	-197	1290	+164	--	--
23	771	684	-87	--	--	--	--
24	1034	790	-244	--	--	--	--
25	1034	523	-511	--	--	--	--
26	75	70	-5	516	+441	--	--
27	15	--	--	1	-14	--	--
28	804	--	--	35	-769	--	--
29	966	--	--	--	--	255	-711
30	259	--	--	--	--	144	-115
31	259	86	-173	--	--	--	--
32	1348	--	--	1016	-332	--	--
33	1654	992	-662	--	--	--	--
34	1897	865	-1032	--	--	--	--
35	1897	362	-1535	--	--	--	--
36**	--	--	--	--	--	--	--
37	1419	521	-898	180	-1239	--	--
38	1591	411	-1180	--	--	--	--
39	2191	391	-1800	--	--	--	--
40	420	662	+242	--	--	--	--
41**	--	--	--	--	--	--	--
Average	997	667	-378	707	-134	199	-413

* A + means greater grass density in the treated area than in the untreated area.
A - means less grass density in the treated area than in the untreated area.
** Not sampled.

Table 15

Frequency of Blue Grama in Untreated and Treated Areas

Area No. a	Untreated b	Pitted c	Difference Between Pitted and Untreated* d	Pitted and Seeded e	Difference Between Pitted and Seeded and Untreated* f	Ripped g	Difference Between Ripped and Untreated* h
1	88.0	--	--	46.0	-42.0	--	--
2	88.0	63.0	-25.0	--	--	--	--
3	60.0	53.0	-7.0	--	--	--	--
4	59.0	54.0	-5.0	--	--	--	--
5	59.0	--	--	0.0†	--	--	--
6	59.0	--	--	0.0†	--	--	--
7	0.3	0.0†	--	68.7	+68.4	--	--
8	41.4	73.4	+32.0	--	--	--	--
9	0.0†	0.0†	--	--	--	--	--
10	6.7	21.0	+14.3	17.0	+10.3	--	--
11**	--	--	--	--	--	--	--
12**	--	--	--	--	--	--	--
13**	--	--	--	--	--	--	--
14	21.0	11.7	-9.3	--	--	--	--
15	78.3	41.0	-37.3	0.0†	--	--	--
16	93.0	25.3	-67.7	--	--	--	--
17	78.3	14.7	-63.6	85.0	+6.7	--	--
18	96.0	27.3	-68.7	--	--	--	--
19	100.0	70.0	-30.0	73.0	-27.0	--	--
20	100.0	--	--	81.3	-18.7	--	--
21	74.7	62.7	-12.0	--	--	--	--
22	100.0	86.3	-13.7	87.0	-13.0	--	--
23	78.3	70.3	-8.0	--	--	--	--
24	90.3	62.7	-27.6	--	--	--	--
25	90.3	53.3	-37.0	--	--	--	--
26	0.0	0.0	--	23.2	--	--	--
27	0.0	--	--	0.0†	--	--	--
28	56.2	--	--	0.0†	--	--	--
29	55.3	--	--	--	--	0.0†	--
30	1.3	--	--	--	--	15.0	+13.7
31	1.3	0.0	--	--	--	--	--
32	88.3	--	--	0.0†	--	--	--
33	98.7	57.0	-41.7	--	--	--	--
34	20.7	63.7	+43.0	--	--	--	--
35	20.7	0.7	-20.0	--	--	--	--
36**	--	--	--	--	--	--	--
37	78.3	41.0	-37.3	23.3	-55.0	--	--
38	0.0	33.7	--	--	--	--	--
39	96.0	66.3	-29.7	--	--	--	--
40	6.7	39.3	+32.6	--	--	--	--
41**	--	--	--	--	--	--	--
Average	62.0	45.5	-19.0	56.0	-10.0	15.0	+13.7

* A + means higher frequency of blue grama in the treated area than in the untreated area. A - means lower frequency of blue grama in the treated area than in the untreated area.

** Not sampled.

† No blue grama within sample site; not included in average or difference calculations.

Table 16

Frequency of Russian Thistle in Untreated and Treated Areas

Area No. a	Untreated b	Pitted c	Difference Between Pitted and Untreated* d	Pitted and Seeded e	Difference Between Pitted and Seeded and Untreated* f	Ripped g	Difference Between Ripped and Untreated* h
1	100.0	--	--	65.0	-35.0	--	--
2	100.0	74.0	-26.0	--	--	--	--
3	79.0	68.0	-11.0	--	--	--	--
4	70.3	9.0	-61.3	--	--	--	--
5	70.3	--	--	27.7	-42.6	--	--
6	70.3	--	--	96.7	+26.4	--	--
7	63.0	43.0	-20.0	26.3	-36.7	--	--
8	1.7	0.0†	--	--	--	--	--
9	100.0	1.8	-98.2	--	--	--	--
10	23.3	100.0	+76.7	61.0	+37.7	--	--
11**	--	--	--	--	--	--	--
12**	--	--	--	--	--	--	--
13**	--	--	--	--	--	--	--
14	31.0	73.7	+42.7	--	--	--	--
15	21.7	36.7	+15.0	95.0	+73.3	--	--
16	0.0†	2.7	--	--	--	--	--
17	2.0	0.0†	--	43.0	+41.0	--	--
18	19.0	19.7	+0.7	--	--	--	--
19	0.0†	0.7	--	0.0†	--	--	--
20	0.0†	--	--	21.3	--	--	--
21	0.0†	30.0	--	--	--	--	--
22	0.0†	2.3	--	1.7	--	--	--
23	2.0	4.3	+2.3	--	--	--	--
24	2.3	9.7	+7.4	--	--	--	--
25	2.3	29.0	+26.7	--	--	--	--
26	0.0†	9.4	--	1.8	--	--	--
27	0.0†	--	--	0.0†	--	--	--
28	0.0†	--	--	0.0†	--	--	--
29	11.3	--	--	--	--	38.3	+27.0
30	35.3	--	--	--	--	27.0	-8.3
31	35.3	28.7	-6.6	--	--	--	--
32	0.0†	--	--	0.0†	--	--	--
33	0.0†	10.0	--	--	--	--	--
34	0.0†	3.3	--	--	--	--	--
35	0.0†	95.0	--	--	--	--	--
36**	--	--	--	--	--	--	--
37	21.7	36.7	+15.0	90.0	+68.3	--	--
38	4.3	43.3	+39.0	--	--	--	--
39	19.0	25.7	+6.7	--	--	--	--
40	23.3	76.7	+53.4	--	--	--	--
41**	--	--	--	--	--	--	--
Average	37.8	33.4	+3.7	48.1	+16.6	32.7	+9.4

* A + means higher frequency of Russian thistle in the treated area than in the untreated area. A - means lower frequency of Russian thistle in the treated area than in the untreated area.

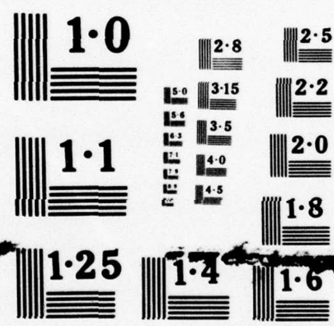
** Not sampled.

† No Russian thistle within sample site; not included in average or difference calculations.

AD-A053 975 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/2
ENVIRONMENTAL BASELINE DESCRIPTIONS FOR USE IN THE MANAGEMENT O--ETC(U)
APR 78 A M REKAS, W L KIRK
UNCLASSIFIED WES-TR-M-77-4-3 NL

2 OF 2
ADA
053975

END
DATE
FILMED
6-78
DDC



NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Table 17

Maximum Height (cm) of Blue Grama in Untreated and Treated Areas

Area No. a	Untreated b	Pitted c	Difference Between Pitted and Untreated* d	Pitted and Seeded e	Difference Between Pitted and Seeded and Untreated* f	Ripped g	Difference Between Ripped and Untreated* h
1	7.0	--	--	33.0	+26.0	--	--
2	7.0	30.0	+23.0	--	--	--	--
3	18.0	40.0	+22.0	--	--	--	--
4	12.0	28.0	+16.0	--	--	--	--
5	12.0	--	--	0.0†	--	--	--
6	12.0	--	--	0.0†	--	--	--
7	3.0	0.0†	--	34.0	+31.0	--	--
8	50.0	36.0	-14.0	--	--	--	--
9	0.0†	0.0†	--	--	--	--	--
10	44.0	47.0	+3.0	8.0	-36.0	--	--
11**	--	--	--	--	--	--	--
12**	--	--	--	--	--	--	--
13**	--	--	--	--	--	--	--
14	11.0	12.0	+1.0	--	--	--	--
15	15.0	14.0	-1.0	0.0†	--	--	--
16	13.0	19.0	+6.0	--	--	--	--
17	17.0	1.0	-16.0	30.0	+13.0	--	--
18	22.0	6.0	-16.0	--	--	--	--
19	16.0	22.0	+6.0	30.0	+14.0	--	--
20	16.0	--	--	32.0	+16.0	--	--
21	20.0	22.0	+2.0	--	--	--	--
22	21.0	24.0	+3.0	37.0	+16.0	--	--
23	17.0	11.0	-6.0	--	--	--	--
24	7.0	31.0	+24.0	--	--	--	--
25	7.0	12.0	+5.0	--	--	--	--
26	0.0†	0.0†	--	57.0	--	--	--
27	0.0†	--	--	0.0†	--	--	--
28	14.0	--	--	0.0†	--	--	--
29	14.0	--	--	--	--	0.0†	--
30	7.0	--	--	--	--	41.0	+34.0
31	7.0	0.0†	--	--	--	--	--
32	34.0	--	--	0.0†	--	--	--
33	31.0	36.0	+5.0	--	--	--	--
34	36.0	30.0	-6.0	--	--	--	--
35	36.0	5.0	-31.0	--	--	--	--
36**	--	--	--	--	--	--	--
37	15.0	14.0	-1.0	18.0	+3.0	--	--
38	0.0†	34.0	--	--	--	--	--
39	22.0	30.0	+8.0	--	--	--	--
40	44.0	21.0	-23.0	--	--	--	--
41**	--	--	--	--	--	--	--
Average	19.0	21.8	+0.7	31.0	-10.4	41.0	+34.0

* A + means greater maximum height of blue grama in the treated area than in the untreated area. A - means less maximum height of blue grama in the treated area than in the untreated area.

** Not sampled.

† No blue grama within sample site; not included in averages.

Table 18

Average Height (cm) of Blue Grama in Untreated and Treated Areas

Area No. a	Untreated b	Pitted c	Difference Between Pitted and Untreated* d	Pitted and Seeded e	Difference Between Pitted and Seeded and Untreated* f	Ripped g	Difference Between Ripped and Untreated* h
1	3.0	--	--	4.0	+1.0	--	--
2	3.0	3.0	0.0	--	--	--	--
3	4.0	4.0	0.0	--	--	--	--
4	5.0	7.0	+2.0	--	--	--	--
5	5.0	--	--	0.0†	--	--	--
6	5.0	--	--	0.0†	--	--	--
7	0.7	0.0†	--	8.3	+7.6	--	--
8	15.7	8.6	-7.1	--	--	--	--
9	0.0†	0.0†	--	--	--	--	--
10	4.7	5.3	+0.6	2.0	-2.7	--	--
11**	--	--	--	--	--	--	--
12**	--	--	--	--	--	--	--
13**	--	--	--	--	--	--	--
14	2.3	3.3	+1.0	--	--	--	--
15	2.7	3.0	+0.3	0.0†	--	--	--
16	5.3	7.7	+2.4	--	--	--	--
17	2.3	1.0	-1.3	1.7	-0.6	--	--
18	3.0	3.0	0.0	--	--	--	--
19	1.7	3.7	+2.0	5.0	+3.3	--	--
20	1.7	--	--	4.7	+3.0	--	--
21	4.0	3.3	-0.7	--	--	--	--
22	3.0	3.3	+0.3	5.0	+2.0	--	--
23	2.3	2.0	-0.3	--	--	--	--
24	3.0	5.0	+2.0	--	--	--	--
25	3.0	2.7	-0.3	--	--	--	--
26	0.0†	0.0†	--	8.4	--	--	--
27	0.0†	--	--	0.0†	--	--	--
28	4.7	--	--	0.0†	--	--	--
29	3.3	--	--	--	--	0.0†	--
30	1.7	--	--	--	--	7.7	+6.0
31	1.7	0.0†	--	--	--	--	--
32	4.0	--	--	0.0†	--	--	--
33	3.0	6.3	+3.3	--	--	--	--
34	9.7	3.3	-6.4	--	--	--	--
35	9.7	1.3	-8.4	--	--	--	--
36**	--	--	--	--	--	--	--
37	2.7	3,0	+0.3	1.7	-1.0	--	--
38	0.0†	5.3	--	--	--	--	--
39	3.0	3.0	0.0	--	--	--	--
40	4.7	4.7	0.0	--	--	--	--
41**	--	--	--	--	--	--	--
Mean	4.0	4.0	-0.5	4.5	-1.6	7.7	+6.0

* A + means greater average height of blue grama in the treated area than in the untreated area. A - means less average height of blue grama in the treated area than in the untreated area.

** Not sampled.

† No blue grama within sample site; not included in average or difference calculations.

Table 19

Flowering and Fruiting of Blue Grama in

Untreated and Treated Areas*

	Pitted	Pitted and Seeded	Ripped	Untreated
Flowering or fruiting structures present	13 (48%)**	6 (40%)	1 (50%)	22 (61%)
Flowering or fruiting structures absent	10 (37%)	3 (20%)		10 (28%)
Blue grama absent	4 (15%)	6 (40%)	1 (50%)	4 (11%)
Total	27 (100%)	15 (100%)	2 (100%)	36 (100%)

* From Tables 6-9.

** Number of areas (percent of total).

Table 20

Comparison Between Grasses Seeded, Grasses Present in 1977, and Number of Years Since Seeding

Area Number	Grasses Seeded*	Grasses Present** in 1977	Number of Years Since Seeding
1	Blue grama	Blue grama	6
3	Russian wildrye Pubescent wheatgrass	Not sampled	
5	Pubescent wheatgrass Russian wildrye Crested wheatgrass Slender wheatgrass	Russian wild rye Wheatgrass (Crested?) Squirrel tail	2
6	Pubescent wheatgrass Russian wildrye Crested wheatgrass Western wheatgrass	Alkali sacaton Squirrel tail Three awn	2
7	Western wheatgrass Crested wheatgrass	Blue grama Ring muhly Squirrel tail	2
10	Crested wheatgrass	Crested wheatgrass Blue grama Squirrel tail	3
15	Blue grama	Three awn Alkali sacaton Tumblegrass Squirrel tail	2
17	Blue grama	Blue grama Ring muhly	4
19	Blue grama Side-oats grama	Blue grama Alkali sacaton Three awn	3 1
20	Blue grama Pubescent wheatgrass	Blue grama Squirrel tail Alkali sacaton	3
22	Blue grama	Blue grama Alkali sacaton Squirrel tail Three awn Ring muhly	4
26	Pubescent wheatgrass Russian wildrye	Wheatgrass (Pubescent?) Blue grama Sand dropseed	2
27	Pubescent wheatgrass Slender wheatgrass Russian wildrye	Wheatgrass (Pubescent?)	2
28	Blue grama	Indian ricegrass	6
32	Crested wheatgrass	Crested wheatgrass Three awn Tumblegrass	2
37	Blue grama	Blue grama Squirrel tail	2

* From Table 2.
** From Table 7.

Table 21

Results of Grass Seeding in Pitted and Seeded Areas

Grass Species Seeded	Number of Areas Seeded*	Number of Seeded Areas Where Grass Was Still Present in 1977**	Percent of Areas Showing Successful Seeding
Blue grama (native)	8	6	75
Pubescent wheatgrass (adapted)	6	2	33
Crested wheatgrass (adapted)	5	2	40
Russian wildrye (adapted)	5	1	20
Slender wheatgrass (adapted)	2	0	0
Western wheatgrass (adapted)	2	0	0
Side-oats grama (native)	1	0	0

* From Table 2.
** From Table 7.

Table 22

Summary of Annual Precipitation Data at Four Weather Stations Within a 30-Mile Radius of Fort Carson*

Station	Annual Precipitation, in. (cm)**			Number Years of Record
	Minimum	Average	Maximum	
Colorado Springs Airport	8.59 (21.82)	14.86 (37.74)	25.63 (65.10)	28
Fountain	8.43 (21.41)	14.14 (35.92)	26.61 (67.59)	32
Pueblo Airport	6.27 (15.93)	11.36 (28.85)	23.09 (58.65)	22
Butts Airfield	8.69 (22.07)	12.87 (32.69)	19.07 (48.44)	7
Combined mean		13.31 (33.81)		

* From Reference 18.

** Total annual rainfall and snowfall expressed as inches (and centimetres) of water.

Table 23

Annual and Combined Average Annual Precipitation for the Period 1971-1976 at Four Weather Stations Within a 30-Mile Radius of Fort Carson

Station	Annual Precipitation, in. (cm)*							
	1971	1972	1973	1974	1975	1976	Six-Year Average	Difference Between Six-Year and Station Average**
Colorado Springs Airport	11.86 (30.12)	20.03 (50.88)	14.11 (35.84)	9.50 (24.13)	11.77 (29.90)	20.34 (51.66)	14.60 (37.08)	-0.26 (-0.66)
Fountain	11.52 (29.26)	14.30 (36.32)	13.55 (34.42)	9.82 (24.94)	10.85 (27.56)	8.65 (21.97)	11.45 (29.08)	-2.69 (-6.83)
Pueblo Airport	8.28 (21.03)	11.93 (30.30)	13.20 (33.53)	9.40 (23.88)	9.88 (25.10)	13.42 (34.09)	11.02 (27.99)	-0.34 (-0.86)
Butts Airfield	11.40 (28.96)	12.75 (32.38)	11.34 (28.80)	8.69 (22.07)	13.10 (33.27)	18.48 (46.94)	12.62 (32.06)	-0.25 (-0.63)
Combined average	10.76 (27.33)	14.75 (37.47)	13.05 (33.15)	9.35 (23.75)	11.40 (28.96)	15.22 (38.66)	12.42 (31.55)	-0.89 (-2.26)

* Total rainfall and snowfall expressed as inches (and centimetres) of water.
** A negative number indicates less annual precipitation in inches in the six-year record period than in the station record period.

Table 24

Examples of Variability in Rainfall Recorded in 1976 at Selected Weather Stations

Within a 30-Mile Radius of Fort Carson

Station	Rainfall, in. (cm)						
	22 May 76	6 Jun 76	21 Jul 76	1 Aug 76	2 Aug 76	3 Aug 76	17 Sep 76
Colorado Springs Airport	1.06 (2.69)	1.37 (3.48)	0.20 (0.51)	2.59 (6.58)	1.75 (4.44)	0.46 (1.17)	1.15 (2.92)
WES Clover Ditch	0.49 (1.24)	1.04 (2.64)	0.04 (0.10)	--	--	--	1.32 (3.35)
Butts Airfield	0.10 (0.25)	0.01 (0.02)	0.72 (1.83)	0.53 (1.35)	1.52 (3.86)	0.02 (0.05)	0.63 (1.60)
Fountain	--	0 (0.0)	0 (0.0)	0.48 (1.22)	1.09 (2.77)	1.01 (2.56)	1.05 (2.67)
WES Red Devil	0.17 (0.43)	0.91 (2.31)	1.50 (1.27)	0.31 (0.79)	2.27 (5.77)	0.01 (0.02)	0.03 (0.08)
WES Turkey Creek	--	0.41 (1.04)	0.19 (0.48)	0.28 (0.71)	1.85 (4.70)	0.21 (0.53)	0 (0.0)
Pueblo Airport	0.01 (0.02)	0.01 (0.02)	T	0.01 (0.02)	0.36 (0.91)	0.01 (0.02)	0 (0.0)

Note: -- = no record; 0 = no rainfall; T = trace.

Table 25

Distance Between Selected Weather Stations Within a 30-Mile Radius of Fort Carson

	Distance, miles (km)						
Station	Colorado Springs Airport	WES Clover Ditch	Butts Airfield	Fountain	WES Red Devil	WES Turkey Creek	Pueblo Airport
Colorado Springs Airport	0 (0.0)	6.3 (10.0)	5.3 (8.5)	7.6 (12.2)	22.7 (36.6)	26.6 (42.8)	37.3 (60.0)
WES Clover Ditch	6.3 (10.1)	0 (0.0)	3 (4.8)	3 (4.8)	17 (27.4)	19.6 (31.6)	32.6 (52.5)
Butts Airfield	5.3 (8.5)	3 (4.8)	0 (0.0)	3.9 (6.3)	13.6 (21.9)	17.7 (28.5)	30.6 (49.3)
Fountain	7.6 (12.2)	3 (4.8)	3.9 (6.3)	0 (0.0)	17 (27.4)	19.6 (31.6)	30 (48.3)
WES Red Devil	22.7 (36.6)	17 (27.4)	13.6 (21.9)	17 (27.4)	0 (0.0)	8.2 (13.2)	27.5 (44.3)
WES Turkey Creek	26.6 (42.8)	19.6 (31.6)	17.7 (28.5)	19.6 (31.2)	8.2 (13.2)	0 (0.0)	19.6 (31.6)
Pueblo Airport	37.3 (60.0)	32.6 (52.5)	30.6 (49.3)	30 (48.3)	27.5 (44.3)	19.6 (31.6)	0 (0.0)

Table 26

Comparison Between Combined Average Annual Precipitation for Six Years (1971-1976) and Combined Mean Annual Precipitation for All Years of Record at Four Weather Stations Within a 30-Mile Radius of Fort Carson

	Annual Precipitation, in. (cm)*		
Year	Combined Average**	Combined Mean†	Difference Between Combined Average and Combined Mean††
1971	10.76 (27.33)	13.31 (33.81)	-2.54 (-6.45)
1972	14.75 (37.46)	13.31 (33.81)	+1.44 (3.66)
1973	13.05 (33.15)	13.31 (33.81)	-0.26 (-0.66)
1974	9.35 (23.75)	13.31 (33.81)	-3.96 (-10.06)
1975	11.40 (28.96)	13.31 (33.81)	-1.91 (-4.85)
1976	15.22 (38.66)	13.31 (33.81)	+1.91 (4.85)

* Total rainfall and snowfall expressed as inches (and centimetres) of water.

** Average of the annual precipitation records at the four stations during the year indicated (Table 23).

† Mean of the average annual precipitation records for all years of precipitation records at the four stations (Table 22).

†† A negative number indicates less annual precipitation than the mean for the four stations. A positive number indicates more annual precipitation than the mean for the four stations.

Table 27

Comparison Between Results of Pitting and Terrain Conditions in Sample Sites

		Results of Pitting				Terrain Conditions in Sample Sites		
Area Number a	Year Pitted b	Percent Vegetation Cover c	Percent Grass Cover d	Vegetation Density stems/m^2 e	Grass Density culms/m^2 f	USDA Textural Soil Classification g	Slope % h	Elevation ft (m) i
2	1969	+5.0	-4.0	+748	+619	Silty loam	3	5500 (1677.5)
3	1974	-2.0	+5.0	+162	+191	Clay loam	3	5800 (1769.0)
4	1969	-21.8	-1.6	-91	-26	Loam	5	5760 (1756.8)
7	1974	+6.0	+3.8	+225	+119	Loam	4	5640 (1720.2)
8	1970	+1.4	+2.7	-182	-181	Loam	2	5580 (1701.9)
9	1969	+5.2	+16.6	+9	+397	Silty loam	6	5720 (1744.6)
10	1973	+8.1	-10.5	+44	-124	Silty loam	3	5760 (1756.8)
14	1974	-13.2	-3.0	-41	-72	Clay	5	5780 (1762.9)
15	1975	-6.2	-15.3	-785	-898	Sandy loam	5	5960 (1817.8)
16	1974	+13.9	-12.8	-240	-472	Sandy loam	10	5880 (1793.4)
17	1972	-16.3	-14.8	-689	-673	Sandy loam	5	5920 (1805.6)
18	1972	+27.2	-29.3	-1380	-1789	Sandy loam	5	6040 (1842.2)
19	1975	+6.7	+5.7	+749	+744	Loam	5	6160 (1878.8)
21	1973	-9.2	-15.3	+114	+48	Sandy loam	7	6140 (1872.7)
22	1972	-7.0	-6.7	-179	-197	Sandy loam	2	6040 (1842.2)
23	1972	-1.9	-2.7	-64	-87	Sandy loam	5	5960 (1817.8)
24	1973	-15.4	-15.1	-229	-244	Silty loam	3	5840 (1781.2)
25	1973	-13.7	-18.7	-408	-511	Silty loam	7	5800 (1769.0)
26	1974	+0.4	-2.2	+80	-5	Clay loam	2	5380 (1640.9)
31	1974	+2.1	-3.9	-115	-173	Clay loam	4	5480 (1671.4)
33	1974	-11.4	-15.5	-616	-662	Loam	3	6400 (1952.0)
34	1974	-24.4	-26.0	-945	-1032	Loam	5	6360 (1939.8)
35	1974	+23.6	-31.7	-981	-1535	Loam	5	6400 (1952.0)
37	1974	-6.2	-15.3	-785	-898	Sandy loam	5	5960 (1817.8)
38	1975	-16.5	-16.5	-989	-1180	Loam	3	6120 (1866.6)
39	1972	-15.3	-16.7	-1770	-1800	Sandy loam	2	6400 (1952.0)
40	1973	+7.4	-1.0	+249	+242	Silty loam	3	5700 (1738.5)

Table 28

Comparison Between Results of Pitting and Seeding and Terrain Conditions in Sample Sites

		Results of Pitting and Seeding				Species*	Terrain Conditions Pitted and Seeded Sample Site		
Area No. a	Year Pitted and Seeded b	Percent Vegetation Cover c	Percent Grass Cover d	Vegetation Density stems/m^2 e	Grass Density culms/m^2 f	Seeded Common Name g	USDA Textural Soil Classification h	Slope % i	Elevation ft (m) j
1	1971	-4.0	-12.0	-613	-673	a	Silty loam	2	5460 (1665.3)
5	1975	-13.1	-8.3	-425	-415	c,b,d,f	Loam	3	5680 (1732.4)
6	1975	-2.8	-9.6	-480	-565	b,c,d,e	Loam	2	5680 (1732.4)
7	1975	+24.0	+32.1	+1132	+1147	d,e	Loam	4	5640 (1720.2)
10	1974	+6.0	-9.1	+46	-55	a	Silty loam	3	5760 (1756.8)
15	1975	-10.5	-26.9	-548	-1382	a	Sandy loam	5	5960 (1817.8)
17	1973	+15.8	+7.5	+319	+248	a	Sandy loam	5	5920 (1805.6)
19	1976	+16.1	+10.8	+528	+514	d,g	Loam	5	6160 (1878.8)
20	1974	+12.9	+11.8	+935	+917	a,c	Loam	3	6160 (1878.8)
22	1973	-0.3	-2.2	+227	+164	a	Sandy loam	2	6040 (1842.2)
26	1975	+6.8	+10.2	+452	+441	c,d	Clay loam	2	5380 (1640.9)
27	1975	-14.6	-1.0	+22	-14	b,f,c	Clay loam	3	5580 (1701.9)
28	1971	-17.8	-19.9	-775	-769	a	Loam	4	5900 (1799.5)
32	1975	-4.3	+0.8	-341	-332	d,h	Loam	5	6360 (1939.8)
37	1975	+0.4	-23.0	-1122	-1239	a	Sandy loam	5	5960 (1817.8)

* Species code: (a) blue grama (native); (b) Russian wildrye (adapted); (c) pubescent wheatgrass (adapted); (d) crested wheatgrass (adapted); (e) western wheatgrass (native); (f) slender wheatgrass (native); (g) side oats (native); and (h) yellow clover (adapted).

Table 29

Comparison Between Results of Ripping and Terrain Conditions in Sample Sites

		Results of Ripping				Terrain Conditions in Sample Sites		
Area Number a	Year Ripped b	Percent Vegetation Cover c	Percent Grass Cover d	Vegetation Density stems/m^2 e	Grass Density culms/m^2 f	USDA Textural Soil Classification g	Slope % h	Elevation ft (m) i
29	1974	-7.0	-17.7	-680	-711	Sandy loam	4	5510 (1680.6)
30	1974	+5.6	-2.1	+76	-115	Clay loam	4	5480 (1671.4)

APPENDIX A: REVIEW OF METHODS FOR CONTROLLING SOIL EROSION

1. A literature review and consultations with range management specialists were undertaken to identify vegetative and mechanical control methods that could be applied as alternative or improved methodologies for control of soil erosion on Fort Carson. The methods that appear to have potential for success at Fort Carson are listed in Table A1 and are discussed below.

Vegetative Control Methods

Establishment of vegetative cover

2. Vegetation is one of the most important factors influencing soil erosion.* It can be used to control water-induced soil erosion because it performs a number of important functions, including: shielding the soil from the impact of the raindrops; reducing surface flow velocities; maintaining a pervious soil surface resulting in greater infiltration; and removing subsurface water between storm events by transpiration that also results in greater infiltration. Furthermore, vegetation can effectively control wind erosion, since the stems and leaves shield the soil from wind and the roots bind soil particles together.

3. Reforestation. Reforestation is the establishment or reestablishment of trees in an area for erosion control. Trees are commonly used as ground cover for exposed soils, as shelterbelts in areas faced with wind erosion, and as streambank soil binders in areas endangered by bank scour.

4. The effectiveness of shelterbelts depends upon wind velocity; wind direction; and shape, width, height, and porosity of the shelterbelt.[19]** If the wind blows at a right angle to a shelterbelt, wind

---

* A discussion of the influences of vegetative cover on soil loss in selected watersheds on Fort Carson is contained in Report 4 of this series.

** Raised numbers refer to similarly numbered items in the References at the end of the main text.

velocity is reduced 70 to 80 percent near the belt, but no reduction in velocity occurs at a distance (leeward) equal to 30 to 40 times the belt height. Tree shelterbelts, which are normally one to three rows of trees in width, are usually planted along field boundaries. These shelterbelts usually contain openings as large as 350 to 450 ft on highly erodable soils, or 500 to 650 ft for moderately erodible soils. Dense growing tree species are preferred for wind erosion control. Tree species planted for shelterbelts in the Central Plains include carangana, tamarisk, sumac shrubs, plum, Siberian elm, honey locust, plains cottonwood, red cedar, and Virginia or Ponderosa pine. The disadvantages of establishing shelterbelts at Fort Carson include the high initial cost, the length of time to become established, and the probability that irrigation is needed to ensure survival of newly planted trees.

5. Trees can be planted along streambanks to control erosion in areas where grasses fail to become established because of bank sloughing or where grasses do not provide effective long-term protection. Common tree species used for this purpose include willows, cottonwoods, and poplars. The same difficulties in tree culture described for shelterbelts also apply here; however, soil moisture is usually greater in the streambanks or gullies than in upland areas. Trees for both shelterbelts and streambank protection should be selected from nursery stock, since these trees are healthier, bushier, and have better developed root systems than trees transplanted from woodlands.

6. Regrassing. The seeding of eroding areas with fast-growing annual or perennial grasses is the quickest temporary method of controlling both water- and wind-induced soil erosion. Permanent soil stabilization can usually be achieved with the use of long-lived native or adapted perennial grasses. The references reviewed emphasized the need for adequate precipitation and good cultural methods to ensure successful range seedings.[20-23] Adequate precipitation is defined as the amount of precipitation that results in sufficient soil moisture for seed germination and subsequent seedling establishment.

7. Good cultural practices include: (a) removal of competing

vegetation, (b) adequate seedbed preparation, (c) seeding grass species native or adapted to the site, (d) seeding the species at the optimum time (season of year), depth, spacing, and rate, and (e) care of the seeded grass stands. Each of these practices (a-e) is discussed in the following paragraphs.

Removal of competing vegetation

8. Many areas to be seeded are covered with annual grasses and weeds that are not permanent and are thus low-value (poor erosion control) vegetation. If this vegetation is not removed, it will compete for moisture with the young seedlings and prevent their establishment. Selection of one of the several available methods to use depends upon (a) the type of existing vegetation (trees, sagebrush, or annual weeds and grasses), (b) the slope, (c) the soil type (clays, silts, loams, sands, or cobbles), and (d) the cost of using the equipment. Of secondary benefit is the fact that most of the methods will also increase soil moisture (because they modify the land surface and thus increase infiltration) and soil fertility (disturbed soil and organic matter will weather and decompose).[24] The following descriptions of the methods of removing competing vegetation include discussions of other benefits (i.e. preparation and seeding of the seedbed) derived from application of the methods.

9. Rotary tilling. A commercial rotary tiller is used to produce 24-in. strips tilled to a 3-in. depth and alternated with 24-in. nontilled strips. At a test site in eastern Montana,[25] the tiller operation removed 50% of the vegetation in the tilled area. This method resulted in a 41% increase in total perennial grass yield. Soil moisture and soil fertility also were increased.

10. Pitting. The pitting implement is a one-way disk modified either by redrilling and mounting on eccentric centers or by cutting away a part of the individual disk blades and leaving the original mounting position. Pits averaging 48 in. long, 6 in. wide, and 4 in. deep are formed when the modified disk is pulled over the soil surface. This treatment was designed to trap runoff but has the additional effect of removing vegetation that could compete with subsequently

planted perennial grasses. Pitting has the advantage of equipment simplicity and application ease but has produced variable results with respect to vegetation removal, soil moisture increases, and vegetation growth. In eastern Montana, pitting removed 15% of the vegetation cover and disturbed an additional 15% of the area treated, soil moisture was not increased on this sandy upland range site, and only a 13% increase in perennial grasses was noted during the six years of the study.[25] On a study site in Arizona, pitting did not remove enough of the competing vegetation, and grass establishment in the seeded stand was not satisfactory (Figure A1).[21] Studies conducted by Wight[24] report 30 to 70% vegetation removal, greatly increased soil moisture, and 30 to 70% increase in forage production. Effectiveness (increased vegetative production) and longevity (length of time before pit is filled in) of the pitting treatment appear to relate to soil types,

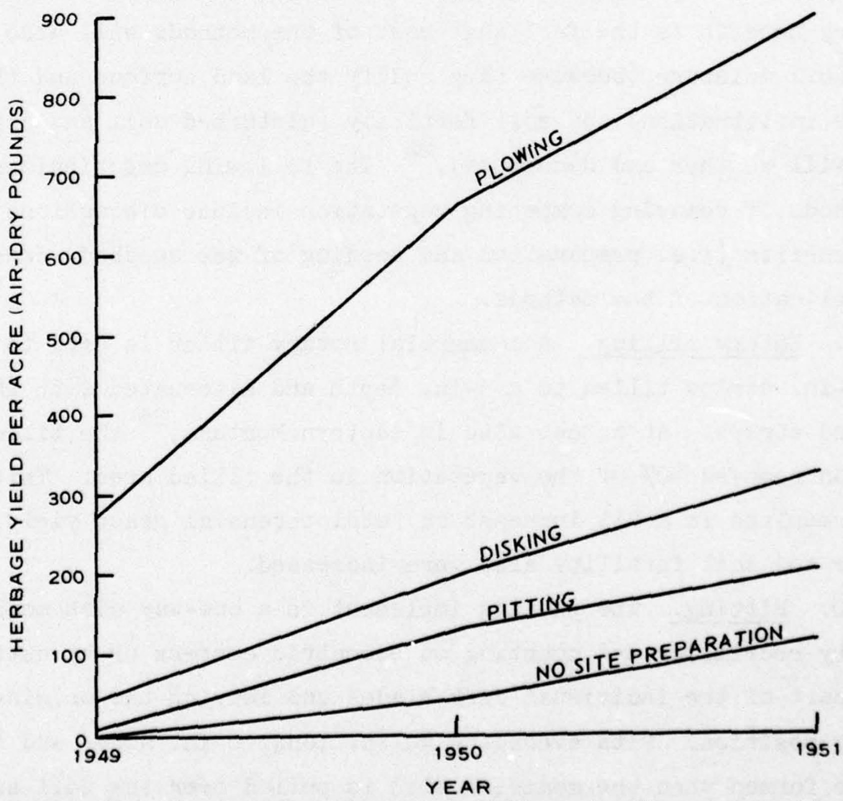


Figure A1. Residual effects of different site-preparation methods on production of crested wheatgrass planted in 1948 at White Horse Lake, Arizona[21] slopes, and precipitation history in the areas where pitting has been done. For example, increases in vegetation production and longevity varied from 13% and 20 years, respectively, on a sandy site[25] to 176% and six years, respectively, on a loam site.[26]

11. Pitting has been used in the southwestern United States, primarily for seedling establishment (because some studies have reported that it increases soil moisture). A recently identified problem with the pits is that water accumulation has often prevented seedling establishment. "To overcome this problem fan-shaped pits or basins were constructed, which allowed for a gradation of elevations from pit bottom to ground surface over a distance of 1.8 to 2.4 m. During dry years, soil water and seedling establishment are limited to the lowest portion of the pits; and during wet years when water is excessive at the lower depths, seedlings establish at some higher elevation along the sloping pit bottom. Fan-shaped basin pits can be constructed by attaching an eccentrically mounted wheel that raises and lowers a dozer blade at desired intervals."[24]

12. Wheatland plowing. This method employs a disk plow with the blades modified to cut a 50- to 80-deg angle to the direction the implement is pulled. It is used widely and successfully to kill shrubs, weeds, and grasses in areas that are relatively level, rock-free, and have medium or light texture soils. The power requirements are lower than for either the moldboard or disk plows, and the resulting seedbed is immediately ready for seeding. A seed bin with seed funnels can be attached to the plow, so seeding can be performed at the same time as plowing.[20]

13. Brushland plowing. The U. S. Forest Service made the plow (an adaption of the Australian Stump-Jump plow) used in this method. The disks are mounted in pairs on free-swinging spring-loaded arms so that the disks can go over obstructions without lifting the whole plow out of the ground. For rough, moderately rocky, or uneven land, this is a most effective plow; however, it will not penetrate well in heavy soils. It is best adapted for use on sagebrush and weed range. This method produces results similar to wheatland plowing and has the

advantage of being able to be used where rocks or tree stumps occur in the area to be seeded.[20,21]

14. Level bench terracing. Level bench terracing is one of the most expensive methods for removing vegetation, preparing the seedbed, and increasing soil moisture. Level benches are described as long, flat terraces, which are level in all directions and diked at the ends and front to provide a water storage capacity.[24] The earth moving required in the construction of level benches effectively removes all vegetation and results in an area prepared for seeding. Level benches with or without contributing watershed areas effectively increase soil water recharge and subsequent forage production. Careful construction techniques are required to prevent fertile topsoil from being removed from the seedbed during dike construction.

15. Contour furrowing. Contour furrowing is a technique involving the construction of furrows 12 to 30 in. wide and 2 to 8 in. deep along a contour. Furrow spacing ranges from 24 to 590 in., but in general, furrow spacing greater than 60 to 70 in. has been ineffective. The USDA Agricultural Research Service has conducted tests at its Northern Plains Soil and Water Research Center in Sidney, Montana, with the Arcadia Model B contour furrower, developed by the USDA Forest Service.[24] This implement makes two furrows 59 in. apart, ranging from 18 to 30 in. wide and up to 8 in. deep. Furrow openers are two offset disks that throw the soil in opposite directions. The openers are preceded by rippers that are adjustable to a 12-in depth below the furrow bottom. Intrafurrow dams can be constructed every 10 to 100 ft with a four-paddle dammer. This furrower can also be equipped with a broadcast seeder.

16. By intercepting and detaining runoff (holds water on soil) and by improving infiltration (breaks up compacted soil), contour furrowing increases soil water recharge. In southeastern Montana, contour furrowing increased infiltration rates from less than 0.19 to more than 0.83 in./hr for up to seven years after treatment.[24] Forage production increases of 100% or more are not uncommon. The main objection to contour furrowing that is expressed by ranchers and

range managers is that the rough surface left by this treatment restricts vehicle travel and the movement and grazing habits of livestock.

17. Contour furrowing effectively removes existing vegetation and has been shown to be an effective means of preparing the seedbed for seeding.[24] In eastern Montana, yield increased up to 30% on contour-furrowed plots seeded with crested wheatgrass (Agropyron cristatum), Russian wildrye (Elymus junceus), meadow brome (Bromus beibersteinni), and alfalfa (Medicago sativa).[24] Reestablishment of native or introduced species in furrow bottoms is sometimes restricted because topsoil has been removed, exposing layers of subsoil that are infertile and high in clay and/or salt content.

18. Ripping. Ripping shatters or breaks up both the soil surface and compacted soil layers that inhibit root growth and development. The ripping implement consists of a heavy steel frame holding a large chisel-shaped blade usually followed by rotating augers. The implement rips narrow, 36- to 48-in. deep furrows and requires the equivalent of a D-8 tractor to pull it. The results of its use include vegetation removal (soil thrown from the furrows covers weeds and grasses), increased soil fertility, decreased surface runoff with subsequent increases in soil moisture, and improved forage production (for as long as 10 years after treatment).[24]

Adequate seedbed preparation

19. Ideal seedbeds, according to SCS standards,[5] for planting perennial grasses in Colorado have the following terrain characteristics:

a. Finished slopes not steeper than 1 (vertical) to 3 (horizontal).

b. No standing water.

c. Stubble cover of sorghum, cane, sudan, broom corn, or small grain.

d. No competing vegetation.

e. Smooth, firm, exposed soil with a loose textured surface.

f. Free of clods, stones, or other material that will interfere with seeding or mulching operations.

g. Length of slope controlled with diversions to retard surface runoff.

h. Four inches or more of top soil.

The most important standards for "suitable seedbeds" reported in the literature surveyed (References 24-26) and recommended by the range experts consulted (Appendix B) included the following:

a. No competing vegetation.

b. Smooth, firm, exposed soil with a loose textured surface.

20. All of the vegetation removal methods listed in paragraphs A8-A18 also provide a seedbed suitable for planting. When additional seedbed preparation is required, wheatland plowing and brushland plowing can be employed, which will leave an area prepared for immediate seeding.

Selection of grass species for seeding

21. Species selected for seeding should be those with growth characteristics that are adapted to the growing conditions of the area.[22] Native species are preferred to adapted species since native species (a) are known to be adapted to the climate and soils, (b) resist invasion by undesirable plants, (c) are easily managed along with the rest of the range grasses in the area, (d) maintain their density and vigor for more than five years, and (e) have a natural appearance in the landscape. Their disadvantages include the following: (a) seeds of desirable native grasses are not always available from grasses grown within 150 miles of the proposed planting site (SCS planting guide specifications[5,27]); and (b) seeds of native grasses cost considerably more than those of introduced (adapted) species (about $4.00/lb for native grasses versus $1.00/lb for introduced). Introduced species that are adapted to the normal growing conditions of the area have the advantages of (a) more rapid establishment, (b) being more palatable to wildlife and cattle, and (c) costing less per pound. Their disadvantages include: (a) most adapted species decline in density and vigor in two to five years; (b) species reactions to extremes in the weather (drought) are not predictable; and (c) the species do not always have a natural appearance in the landscape.

22. Each native and introduced grass species has a specific

growth form and specific soil, slope, elevation, exposure, and climatic requirements. A particular grass species is usually planted for a specific purpose (e.g. for use as cattle forage or hay). The SCS in Colorado has prepared seeding guides[5,28] that make recommendations as to which native or introduced grass species should be planted under each of the following conditions: (a) when a sod-forming or bunching grass is desired; (b) when the site has specific types of soil, exposure, elevation, and slopes; (c) for specific climatic regions of the state; and (d) for a particular purpose. A landowner desiring to plant an area with perennial grasses can make a selection of one or several native or introduced grasses (using the seeding guide) that will meet his particular planting needs and that can be expected to grow satisfactorily considering the site conditions in his area. The SCS technical guides[5,28] also provide specifications on seeding rates, season of seeding, and depth of seeding for each recommended grass species.

Seeding

23. The main requirements of a good seeding method are uniform seed distribution and good control of rate and depth of seeding. These requirements are more easily met by planting seed with a seed drill than when seeds are broadcast. The advantages and disadvantages of the various seeding methods are discussed below.

24. Drilling method. This method uses specially designed grass seed drills that plant grass seeds in rows at a specified depth, with uniform row spacing and at a uniform rate per acre. A typical drill is equipped with a large seed bin, agitator, double disk furrow openers and packer wheels or drag chains, and a separate box for small-seeded grasses.[28] Disk drills are of two types, single disk and double disk. Single-disk drills are used for range seeding and are particularly adapted for seeding hard and bushy seedbeds.[22] Double-disk drills are used for seeding in stubble and on well-prepared (deeply tilled) seed beds. The double-disk drill produces a wider furrow than the single-disk drill, but the seed is covered by the same depth of soil as when using the single-disk drill. The drilling method of seeding has the following advantages: (a) the seed is uniformly distributed; (b) the

seed is uniformly covered; (c) less seed is required; (d) seed is planted at a uniform rate; and (e) drilled grass stands produce more productive grass stands than broadcast stands.[20-22] The disadvantages of drilling are as follows: (a) drilling is not feasible on rough, rocky, or debris-covered soil; (b) drilling is not possible on steep slopes; and (c) the site must be accessible to a farm tractor with attached drill, or farm tractor and truck carrying the drill.

25. Broadcasting methods. There are four methods of broadcast seeding: (a) hand broadcasting, which can be used conveniently in small areas; (b) broadcasting with a hand-powered rotary broadcaster, which can also be used conveniently in small areas; (c) power broadcasting, which uses gasoline engines or power takeoffs from tractors to power large rotary broadcasters and is applicable when large areas are to be seeded; and (d) aerial broadcasting, which uses airplanes or helicopters equipped with venturi-type or dusting hoppers for broadcasting seed in large forested or rocky areas. All methods of broadcast seeding have the advantage of being able to be used on (a) rough, rocky, or debris-covered soil, (b) steep slopes, and (c) sites inaccessible to a seed drill. The disadvantages of broadcast seeding include the following: (a) nonuniform coverage of the seeded area, (b) nonuniform soil coverage of the seed, (c) more seed required than in drilling methods, (d) nonuniform rate of seeding, and (e) less productive grass stands as compared to drilled stands.

Management of seeded stands

26. The SCS standards and specifications[5] recommend the following management practices for seeded stands: (a) protection from people, livestock, and vehicles; (b) fertilizer application; (c) mulching; and (d) supplemental irrigation to aid in the establishment of a permanent stand.

27. Protection from people, livestock, and vehicles. The SCS recommends protection for at least two years or until the seeded grasses are established. In some areas, limited use may be allowed for an indefinite period.

28. Fertilizer application. The SCS recommends[5] application of

at least 50 lb/acre of nitrogen immediately prior to seeding on areas requiring soil stabilization for erosion control, but more recent studies[29] indicate that since nitrogen was a growth-limiting factor on most Great Plains sites, the grass could use more of the nitrogen if the fertilizer were applied at a later stage of growth. This procedure (later application of nitrogen) allows more of the growing grass, rather than the weeds existing on the site, to use the nitrogen. Annual application of 40 lb/acre of nitrogen could be expected to double forage yields on most Great Plains sites.[29] Higher rates of nitrogen application (above 100 lb/acre) have increased forage yields 100 to 200 percent with a carryover or residual effect that lasts for several years (yield increases of 40% in the sixth year after a single application of 100 lb/acre of nitrogen).[29] Most nitrogen is applied by broadcasting ammonium nitrate or ammonium sulfate fertilizers.

29. Mulching. Mulching is particularly recommended for steep slopes (>15 deg) where seed and soil are likely to be carried downslope by precipitation before the grass stand becomes established. Mulches are used to dissipate the energy of raindrops, reduce water runoff, reduce wind erosion, conserve soil moisture, prevent surface crusting, and protect germinating seeds and seedlings.[30] The types of mulches available include jute or plastic netting, woodchips, hay, wheat straw, wood cellulose, and combinations of these with adhesive materials, such as asphalt and latex.[31] Mulches are applied by hand, with power broadcasters (blown mulches, haystraw, and wood cellulose), and more recently as part of a combination procedure whereby wood cellulose, fertilizer, and seed in an aqueous solution are mechanically applied to an area.[7]

30. Supplemental irrigation. This grass stand management method is necessary only when normal precipitation is inadequate for the germination and establishment of the grass. It is also limited to those areas where a water supply exists that is large enough to supply water to the entire seeded area. Soil should be kept moist for a period of six to eight weeks following seeding for effective germination and establishment of the grass stand.[31]

Mechanical Control Methods

31. Mechanical control methods are erosion control measures that use physical methods rather than living vegetation to control erosion. Both wind and water erosion can be controlled using mechanical control methods, such as tillage, land forming, bank stabilization, and mulching. Several methods that appear to have potential for use at Fort Carson are listed in Table A1 and discussed below.

Tillage methods

32. Tillage methods are land surface modifications that control wind erosion by increasing soil cloddiness (clods are large enough to resist blowing and shelter other erodible materials), surface roughness (ridges and depressions alter wind speed by absorbing and deflecting part of the wind energy), and soil moisture (tilled land absorbs more precipitation, and moist soil resists blowing more than dry soil). These methods also control water erosion by reducing the amount of precipitation (water) that can become runoff. In tilled areas, soil permeability (i.e., soil surface is fractured so that precipitation infiltrates soil rather than becoming runoff) and infiltration (i.e., precipitation is impounded and retained on soil surface so that infiltration of precipitation can take place over longer periods of time) are increased. Runoff is checked directly (once it has started) by impoundment and retention (runoff infiltrates soil) and by diversion (runoff is diverted to an area where it can be impounded and retained). Tillage methods include pitting, ripping, rotary tilling, and contour furrowing, which were previously described as vegetation removal methods (see paragraphs A8-A18), as well as harrowing and cultivating, which are described below.

33. Harrowing. To break up the surface soil, this method uses either the common spring-tooth or the spike-tooth harrow, which brings up clods and causes ridging of the soil. Since the spring-tooth harrow penetrates deeper, it is more efficient that the spike-tooth harrow.

34. Cultivating. The two types of cultivators are field cultivators (also called duckfooted cultivators) and chisel plows. Field

cultivators have flexibility of operating depth, tillage point, and sparing between shanks. While the field cultivator is more commonly used for cultivating fallow land and preparing the seedbed, it also increases surface roughness and brings clods to the surface. Chisel plows are constructed more rigidly than field cultivation for deeper tillage and thus produce a surface that is rougher and more cloddy. In cultivated fields, the chisel plow has been used extensively for emergency tillage to control wind erosion.

Land forming methods

35. Land forming methods, such as bench terracing, trenching, and construction of barriers, are designed to reshape the land to intercept, divert, and retard water runoff for wind erosion control. While such methods are not extensively used for wind erosion control, at least one, bench terracing, has been shown to reduce soil loss from wind erosion.[19]

36. Bench terracing. Bench terraces that are long, flat, and level in all directions are constructed across the slope of the land. They serve to break long slopes and usually have dikes at the ends and front to provide a water storage capacity. The benches effectively increase soil water recharge and retard water erosion.[19,24] The shortening of the length of the slope reduces wind and water erosion, and the grade reduction reduces erosion due to runoff.[19]

37. Trenching. Trenching methods are used to control surface runoff, and subsequent erosion, sedimentation, and flooding.[24,32] Trenches or diversions are constructed across the slope to intercept and divert runoff or to intercept and retain runoff until it infiltrates the soil. Trenches designed to divert runoff consist of a channel and dike. One end of the channel, the outlet, is lower than the other and diverts runoff to an area (stabilized with vegetation or rocks) that can safely receive the runoff without eroding. Trenches designed to retain runoff have level channels with no outlets and are constructed large enough to store all the runoff from the upslope area. This latter type of trench has been used exclusively in mountainous terrain on 30 to 70% slopes. Soil depth above bedrock must be

sufficient to permit the construction of the trenches. Trenching has proved to be effective in controlling runoff from badly deteriorated land subject to high-intensity summer rainstorms.[24]

38. Diversions should have a capacity sufficient to carry runoff from the largest storm that is likely to occur about once in 10 years.[32] The velocity of water flow is of major importance in the design of a diversion and thus should be kept as high as will be safe for maintaining the channel configuration. Safe velocities for different channel conditions are as follows:[32]

Type of Channel	Velocity, fps
Base Channel	
Sand	1.5
Other soils	2.0
Poor channel vegetation	3.0
Fair channel vegetation	4.0
Good channel vegetation	5.0

A gradient of 6-12 in./100 ft (or more, with a permanent vegetation cover) usually ensures that nonerosive velocities are maintained even under maximum flows.[32]

39. The depth of the water channel should seldom be less than 18 in. A minimum cross-sectional area of 7.5 sq ft is suggested for watersheds of 1-6 acres, while those of 6-10 acres need a depth of at least 24 in. and a minimum cross-sectional area of 12 sq ft. The terrace type of diversion ditch is being used extensively where the area of the watershed does not exceed 5 or 6 acres (Figure A2, cross sections A and B). For larger watersheds, however, a different cross section (Figure A2, cross section C) is suggested, especially on steep slopes.[33]

40. Barriers. Barriers used for wind erosion control include snow fences, solid wooden or rock walls, and earthen embankments. Their effectiveness depends upon the wind direction and velocity and on the shape, width, and porosity of the barrier.[19] These barriers are very effective (wind velocity is reduced 70 to 80%) when the wind blows at right angles to the barrier, but the area protected is relatively short (no velocity reduction at a distance equal to 30 to 40

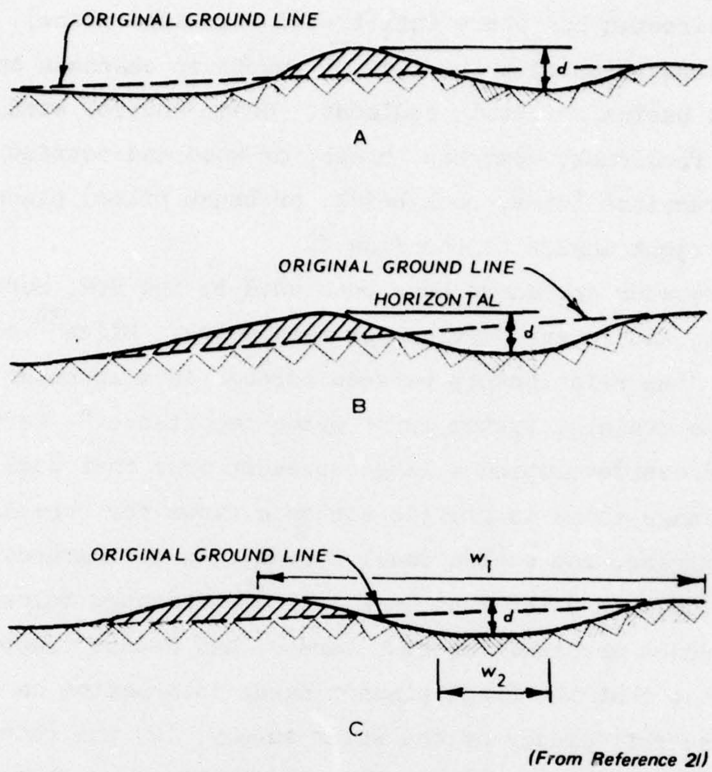


Figure A2. Diversion-ditch cross sections: A Terrace-diversion ditch for gentle slopes. Construction from both sides. Minimum value of d about 18 in. (45.7 cm). B. Terrace-type diversion ditch for steeper slopes. Construction generally from the upper side only. Minimum value of d about 18 in. (45.7 cm). C. This type of diversion ditch is suggested for watersheds exceeding 10-12 acres (0.04-0.05 kilometres^2), especially for the steeper slopes. Minimum value of d should be 22 in. (55.9 cm). Side slopes should be at least 3 to 1 where land slopes permit. (See Farmers' Book, 1813, U. S. Department of Agriculture)(Soil Conservation Service)

times the barrier height). Therefore, wind barriers primarily control only severe wind erosion in limited areas. Barriers or floodwater spreaders used for water erosion control include dikes, berms, and channel grade control (drop) structures. The first two to intercept and divert runoff and require stable outlets (areas to which the runoff can be safely directed and where infiltration can take place). Channel grade control structures slow the flow of runoff in channels and provide small catchment basins to retain sediment. Grade control structures may be constructed from rock, concrete, brush, or wood and consist of a series of obstructions (dams, rock berms, or brush piles) placed across the channel at right angles to the flow.[32]

41. Floodwater spreaders have been used by the SCS, Bureau of Land Management, and Forest Service for many years. Miles[34] of the SCS indicated that "the relationship between acreage in a spreader system and acreage in a drainage system is of prime importance." Care is needed to avoid overdeveloping a large spreader area that does not have sufficient drainage alone to provide adequate flows for spreading or, on the other extreme, has such a small spreading area compared with the drainage that too much water runs back into the drainage below the spreader and causes erosion. Stokes, Larson, and Pearse[3] support Miles and suggest that the range planner needs information on two points to decide on the sufficiency of the water supply: (a) the rate of peak flow per second, and (b) the total volume available in a flow event, which will occur often enough to justify building the system. They list topography, rainfall, soil, vegetation, and available runoff records as factors to consider when potential water supply is estimated.

42. Sediment basins. Temporary sediment basins are used to store runoff and sediment from construction sites until the site has been stabilized with permanent vegetation, at which time the basin is graded into the surrounding landscape. Permanent sediment basins are constructed with a large enough storage capacity to hold several years' accumulation of sediment. Both types of basins (temporary and permanent) have spillways to route runoff from the basins to stable ground below the basins where the runoff can continue down channel without overtopping and eroding the basin.

Bank stabilization methods

43. The WES has recently (March 1977) completed a report which reviews the streambank stabilization methods used in the United States.[35] The review indicated that the methods used to stabilize a

particular segment of streambank depended upon the type of streambank erosion* that was occurring as well as the availability of materials to construct the bank protection structures. Of the 10 most used methods listed in that report, four (stone riprap, fences, gabions, and erosion-control matting) might have application in streambank erosion control on Fort Carson. The following descriptions of these methods were abstracted from the WES report,[35] and the reader is referred to the complete report text for more details.

44. Stone riprap. Riprap consists of rock courses placed along the bank to be protected. If the slope of the bank is irregular, the bank is usually graded prior to riprap placement. Where stones of sufficient size (to resist the hydraulic flow) are available, riprap is usually the first choice among the bank protection methods considered because of the following general advantages:[35]

a. A riprap blanket is flexible and is neither impaired nor weakened by the slight movement of the bank resulting from settlement or other minor adjustments.

b. Local damage or loss is easily repaired by the placement of more rock.

c. Construction is not complicated, and no special equipment or construction practices are necessary.

d. Appearance is natural, hence acceptable, in recreational areas.

e. If riprap is exposed to fresh water, vegetation will often grow through the rocks adding structural value to the bank material and restoring natural roughness.

f. Riprap is recoverable and may be stockpiled for future use.

45. In-place cost of a stone riprap blanket, including bank preparation and transportation of stone, can vary greatly depending on the location and availability of suitable rock. The current estimate for average in-place cost (1976) ranges from $3.50 per yard in an area where stone is readily available to $30 per yard in a metropolitan area where stone must be hauled over long distances.[35]

---

* Natural or man-induced bank recession, channel deepening, or both.

46. Fences. Wire fences are used to solve a variety of bank protection problems on low-gradient streams with discharges less than 500,000 cfs. Fences can be positioned parallel to the bank as well as transverse to the streamflow. Two fences parallel to the bank are sometimes constructed from 3 to 10 ft apart. Brush, hay, or rock is stacked between the fences to provide an extra measure of protection against the erosive action of the water currents. If the fence is constructed parallel to the bank, and the bank is steep enough, a second fence is not required for holding the brush backfill. Fences that are parallel to the bank generally serve as an erosion stop gap measure to allow sufficient time for the establishment of vegetation or to prevent sloughing of the bank. However, fences constructed across part of the stream section promote sediment deposition. A transverse fence can be positioned to deflect debris downstream or to trap it. By constructing the fence so that it is oriented downstream at an oblique angle to the current flow, debris will be deflected into the main channel. This technique is useful if the stream has a heavy debris load and the designer desires to keep the banks clear. Conversely, the fence can be constructed so that it is oriented upstream at an oblique angle to the current flow. Debris is then trapped behind the fence. This construction method is effective for clearing the main channel of debris and serves to encourage sediment deposition. Installed cost of the fencing is $25 to $50 per linear foot (1976) if all material is purchased new; the cost is substantially reduced by the use of secondhand or free materials that are sometimes available.[35]

47. Gabions. Prefabricated gabion cages have been marketed in Europe for many years; however, gabions for the construction of bank protection structures in the United States have been used widely only in the past 15 years. The basic element of the gabion is the cage of "basket." The cage is a rectangular wire-mesh structure divided by wire-mesh diaphragms into cells. The mesh is generally galvanized steel wire, which is coated if the gabions are to be used in a corrosive atmosphere. Each gage is placed and securely wired to its neighbors and then filled with stone. Ideally, the stone should be

slightly larger than the wire mesh and have the maximum possible density. Gabion works are somewhat flexible and are therefore able to accommodate minor changes in bank geometry. The voids between the stones allow bank drainage, which helps to eliminate failures due to excessive hydrostatic pressure. Filter cloths are sometimes used behind gabions to prevent excessive soil losses. Current (1976) in-place costs for gabion works are $40 to $47 per cubic yard.[35]

48. Erosion-control matting. A variety of erosion-control mats are available on the commercial market. Many of these mats are produced from by-products of other manufacturing processes. This type of bank protection is generally installed by hand and secured to the bank with stakes or staples. For some applications, the matting, stakes, and staples are biodegradable. The matting is structured in the form of a web, which allows vegetation to grow through the mat. In many design applications, this is considered to be a short-term bank protection measure that allows either natural vegetation to reestablish itself on an eroding bank or new vegetation adequate time to become established. Some of the currently available mats decompose and add organic matter to the topsoil. Nonorganic webbing has caused some problems during later grass cuttings because of its tendency to become tangled with mower blades. Installed costs (1976) for matting ranges from $0.50 to $0.65 per square yard.[35]

Mulching method

49. While mulching more often occurs in conjunction with establishment of vegetative cover (see paragraph A29), it is also used alone as a mechanical means to control wind and water erosion. The types of mulches available include jute or plastic netting, woodchips, hay, wheatstraw, wood cellulose, and combinations of these sprayed with adhesive materials, such as asphalt and latex. Mulches can be applied by hand or with power broadcasters. Hay and wheatstraw mulches are often distributed and anchored on the soil surface with specially modified disks. These disks have either spike-toothed or spade-toothed disk blades that punch the mulch into the surface. Both types of disks have two gangs of blades, which operate in tandem and at slight angles to the direction of travel.

Table A1

Soil Erosion Control Methods

Wind Erosion Control Methods	Water Erosion Control Methods
Vegetative Control	Vegetative Control
Establishment of vegetative cover	Establishment of vegetative cover
Reforestation	Reforestation
Regrassing	Regrassing
Establishment of shelter belts	
Mechanical Control	Mechanical Control
Tillage	Tillage
Harrowing	Contour furrowing
Ripping	Pitting
Rotary tilling	Ripping
Cultivating	
	Land forming
Land forming	Bench terracing
Bench terracing	Trenching (diversions)
Barriers	Construction of barriers (floodwater spreaders)
	Construction of sediment basins
Mulching	Bank stabilization
	Stone riprap
	Fences
	Gabions
	Erosion-control matting
	Mulching

APPENDIX B: LIST OF RANGE SPECIALISTS CONSULTED

Name	Agency	Location
Dick Blankenship	Pacific Power and Light Company	Casper, Wyo.
Dr. J. Ross Wight	USDA, Agricultural Research Service	Sidney, Mont.
Dr. William McGinnes	USDA, Agricultural Research Service	Fort Collins, Colo.
Dr. David Woolhizer	USDA, Agricultural Research Service	Fort Collins, Colo.
Stuart Parker	USDA, Bureau of Land Management	Cannon City, Colo.
Robert Clark	USDA, Soil Conservation Service	LaJunta, Colo.
Donald Nielsen	USDA, Soil Conservation Service	Colorado Springs, Colo.
Leonard Hendzel	USDA, Forest Service	Lakewood, Calif.
Mike Cistello	Cagwin and Dorward Landscape Contractors	San Rafael, Calif.
Ray Dallen	USDA, Forest Service	Albuquerque, N. Mex.
Ray Adolphson	USDA, Forest Service	Lakewood, Calif.
Ed Dennis	USDA, Soil Conservation Service	LaJunta, Colo.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Rekas, Anthony M B

Environmental baseline descriptions for use in the management of Fort Carson natural resources; Report 3: Inventory and assessment of current methods for rangeland conservation and restoration / by Anthony M. B. Rekas, William L. Kirk. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

71, [57] p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; M-77-4, Report 3)

Prepared for Directorate of Facilities and Engineering, Fort Carson, Colorado, and Office, Chief of Engineers, U. S. Army, Washington, D. C., under Project 4A162121A896, Task 01, Work Unit 006.

References: p. 69-71.

1. Conservation. 2. Dams. 3. Debris. 4. Debris barriers. 5. Environmental data. 6. Environmental management.

(Continued on next card)

Rekas, Anthony M B

Environmental baseline descriptions for use in the management of Fort Carson natural resources; Report 3: Inventory and assessment of current methods for rangeland conservation and restoration ... 1978. (Card 2)

7. Erosion control. 8. Erosion control by vegetation. 9. Fort Carson, Colo. 10. Military installations. 11. Natural resources. 12. Reclamation. 13. Resource conservation. 14. Settling basins (Sediment). 15. Soil erosion. 16. Vegetation. I. Kirk, William L., joint author. II. Fort Carson, Colo. Directorate of Facilities and Engineering. III. United States. Army. Corps of Engineers. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; M-77-4, Report 3.

TA7.W34 no.M-77-4 Report 3