Accuracy of saline seep mapping from color infrared aerial photographs
by John Arthur Beyrau

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Soils
Montana State University
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Abstract:
The formation of saline seeps is a widespread problem in the Great Plains of North America. Detecting and mapping individual saline seeps has been attempted using both aerial photography and satellite imaging systems. High cost, limited sensor resolution and lack of ground information have limited application of the various methods tried.

A remote sensing system developed at Montana State University, based on the use of a light aircraft, 70 mm color infrared (CIR) film and an electronic video image analysis system (LMS) overcomes several of the limitations of previous methods. A large-scale project designed to map saline seeps in 6 counties of northern Montana was initiated in 1986 by the Soil. Conservation Service and the Montana Agricultural Experiment Station. Within the areas covered by the first season's photography, 3 adjacent pairs of townships were selected as test areas. Soil Conservation Service field personnel were trained in the interpretation and mapping of saline seeps. The selected areas were mapped by the field personnel. Due to time and budget constraints, one of each pair of townships was selected and as many saline seeps as -time allowed for were examined for correctness of identification.

Camera defects caused the quality of photography to vary in the 3 areas selected for testing. The best accuracy of identification (79%±9.7%, Toole Co.) was obtained where the highest quality imagery occurred. The lowest accuracy (34%± 12.1%, Liberty Co.) occurred where the quality image was poorest. Rephotographing and remapping Liberty Co. improved accuracy to 94.7%±10%.

Investigation of an area where the imagery obtained in 1986 and in 1987 overlapped allowed the comparison of mapping performed by one interpreter on successive years' photography; that is most of the Shonkin Quadrangle map was mapped twice by one interpreter. Differences in location of mapped saline seeps were few, and the difference in area mapped was 4.9%.

The equipment used to measure the area of the individual saline seeps was tested for consistency. Forty seven separate saline seep polygons were each measured 6 times. The polygon measurements had a mean standard deviation of 2.49%.

A method developed in Montana for mapping saline seeps was about 80% accurate when properly trained air photo interpreters were provided with high quality photography.

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APPROVAL

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

The formation of saline seeps is a widespread problem in the Great Plains of North America. Detecting and mapping individual saline seeps has been attempted using both aerial photography and satellite imaging systems. High cost, limited sensor resolution and lack of ground information have limited application of the various methods tried.

A remote sensing system developed at Montana State University, based on the use of a light aircraft, 70 mm color infrared (CIR) film and an electronic video image analysis system (LMS) overcomes several of the limitations of previous methods. A large-scale project designed to map saline seeps in 6 counties of northern Montana was initiated in 1986 by the Soil Conservation Service and the Montana Agricultural Experiment Station. Within the areas covered by the first season's photography, 3 adjacent pairs of townships were selected as test areas. Soil Conservation Service field personnel were trained in the interpretation and mapping of saline seeps. The selected areas were mapped by the field personnel. Due to time and budget constraints, one of each pair of townships was selected and as many saline seeps as time allowed for were examined for correctness of identification.

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A method developed in Montana for mapping saline seeps was about 80% accurate when properly trained air photo interpreters were provided with high quality photography.

INTRODUCTION

A saline seep is defined as an intermittent or continuous saline water discharge, at or near the soil surface in a topographic position that is downslope from a recharge area. It occurs under dryland farming conditions and causes reduction or total elimination of crops in the affected area as a result of increased concentration of soluble salts in the root zone (Brown et al.,1983). The control of saline seep development is the largest single problem facing dryland agriculture in the Great Plains of North America. Increased salt concentrations have been associated with livestock, fish, and wildlife kills (Harlow, 1974). Deterioration of shallow ground water and surface water resources due to increased concentrations of trace metals and soluble salts has occurred in many areas (Miller et al,1981).

Saline seep development affects much of the northern Great Plains in both the United States and Canada. Climatologic and geologic factors, combined with the alternate year crop-fallow dryland farming practices common in this region are the root cause of saline seeps. Most of the region has a surface mantle of glacial till overlying shale and sandstone units of Cretaceous and Tertiary age. All of these units have relatively high concentrations of soluble salts. Alternate crop-fallow allows excess water to escape through the soil profile into the local groundwater system. The resulting rise in the local water table produces areas of

wetness on the surface as capillary rise draws water from the elevated water table to the surface. As the water evaporates, the salts dissolved in the water are left on the ground surface, forming salt crusts in the more advanced stages of the phenomena.

Saline seeps are frequently classified by stage of development. Three main divisions are usually recognized. Beginning or Stage 1 saline seeps are characterized by lush plant growth. The salts are concentrated deep (1.0 meter or more) in the soil profile. In developing or Stage 2 seeps, plant growth is reduced or eliminated. This is due to the increasing concentration of salts at shallow depth in the soil profile (<1.0m). Crops will be totally eliminated as the salts increase in concentration. Often halophytic plants will be found in developing seeps. Mature or Stage 3 seeps have the salts concentrated at the surface. A salt crust is usually found on Stage 3 saline seep sites. In most cases, little vegetation is present. Kochia and salt tolerant grasses are the most common vegetation. Full descriptions of saline seep stages are in Table 1.

Information on the location and distribution of saline seep is limited. Saline seeps have been surveyed using ground and aerial methods. Ground techniques have proved both costly and time consuming. They are too slow to cover extensive areas during the crop growth period when beginning and developing seeps are most visible.

Remote sensing techniques can improve saline seep surveys because the techniques can be applied to large land areas quickly. They provide a permanent record of terrain conditions during a specific time for future examination. The flexibility of remote sensing allows data to be collected when it is most appropriate to the problem of interest.

The mapping of saline seeps by remote sensing methods has been accomplished with varying success. The methods which give the most promise are those involving near infrared color photographic techniques or satellite-based optical sensor techniques.

One method has shown promise of being sufficiently accurate and more economical than other methods. This is the method reported by Long (1986) and Long and Nielsen (1987). The objective of the present study was to determine if the saline seep mapping technique reported by Long is sufficiently accurate and time effective when applied on a large scale operational basis. Discussion with the Soil Conservation Service in Montana revealed a desire for: 1) an overall accuracy level of at least 80%, and 2) the ability to differentiate beginning saline seeps from naturally occurring wet sites.

LITERATURE REVIEW

Background

Research into the detection and mapping of saline seeps has been extensive and reasonably successful for small areas (<1000 ha). Both color infrared (CIR) photography and space satellite images have been used to map soil salinity. None of these methods have been applied on an operational scale. A few attempts have been made to produce maps of saline seep over large areas (May and Petersen, 1976; Sommerfeldt, et al., 1984; Miller and Bergantino, 1983).

To be useful, any mapping technique must address the following questions: 1) What is the location of the seep? 2) How much area does the seep affect? 3) What is its stage of development or maturity? This information must be reported in a form that is relatively easy to use. All of this must be accomplished in a manner which minimizes labor and expense.

Satellite Based Mapping Techniques

May and Petersen (1976) analyzed the usefulness of LANDSAT-1 multispectral data for the detection and mapping of saline seeps in Chouteau County, Montana. They mapped saline seeps using both supervised and unsupervised techniques based on the signatures of halophytic weeds, salt crusts, and crops. Areas less than 2 hectares could not be accurately mapped due to the limits of scanner resolution. They recommended testing to determine if the results were

applicable to other areas and upgrading to operational status if the results were favorable.

Thompson et al. (1981) used computer analysis techniques on LANDSAT-2 digital data to map salinized land. Data were computer classified into low, moderate and high salinity areas. The results were then manually transferred to base maps. They concluded that moderate to high salinity areas were mapped with the greatest accuracy when the greatest contrast between saline soil and crops occurs. This was between May and mid-July. They later extended their study to test the feasibility of using LANDSAT data for a regional survey of dryland salinity (Thompson et al., 1984). They found the process to be rapid (4 hours per 180 square km scene) and easy. The manual transfer for map production added additional time to the production of final maps.

Sommerfeldt et al. (1984) used Thompson et al.'s (1984) methods to cover all of southern Alberta. They found that their results were very accurate (70 to 80 percent) for moderate to strongly saline areas and less accurate (no percentages given) for low salinity areas. Most errors were due to identification of non-saline bare ground areas as areas of salinity and the 2 hectare resolution limit of the LANDSAT scanners (80 meters). A map of 1:250000 scale was produced.

Detection of Saline Seeps on Aerial Photographs

The use of aerial photography to map saline seeps has been the most favored approach to mapping saline seeps over

large areas. The first extensive research in this area was a regional saline seep remote sensing project beginning in 1975 (Horton and Moore, 1976). Montana, North Dakota and South Dakota combined to determine the usefulness of remote sensing techniques for detection of saline seeps. Accuracy levels were in the 70% to 80% range when CIR imagery was used (Wiersma, 1980). Thermography was also investigated as a tool in seep identification in this study but was not useful unless combined with CIR imagery. Incipient seeps were difficult to identify on all types of imagery.

Three developmental stages were recognized by Dalsted et al. (1979). Incipient, intermediate, or mature classification was based on visual characteristics seen in soils, crops, and weeds. Saline seeps were mapped with 70% and 90% accuracy levels for intermediate and mature seeps, respectively. Incipient seeps were not visible on CIR photos, but could be detected with thermal imaging systems as cooler areas within an otherwise warmer field.

The only large area survey of saline seeps using photographic means is that of Miller and Bergantino (1983). This is a reconnaissance map at 1:1,000,000 scale. White salt crusts were mapped on aerial photographs during flights 3000 feet above local ground level. No seeps that did not present a salt crust visible from the air were recorded. At the same time salinity problems produced by irrigation on the Milk and Yellowstone rivers were recorded. Information on salinity

occurrence from other information sources was also included. The map is not comprehensive but does give an idea of how widespread the salinity problems are.

Long (1986) and Long and Nielsen (1987) present a comprehensive technique for mapping saline seeps. Accuracies of 77 and 85 percent were achieved for beginning and developing/mature seeps, respectively. The method is based on using relatively inexpensive modifications of off the shelf photographic and video equipment described by Long (1986). A key for photo interpretation and ground truth acquisition is a key part of the system devised.

Ground Detection of Saline Seep

Visual Method

Saline seep development is a phenomena that has several causes. All produce the same results; elevated concentrations of salts in the soil which result in the thinning and stunting, or elimination of crops from the site (Brown et al., 1983). The presence of halophytic or salt tolerant plant species often accompanies the crop thinning. Worcester and Seelig (1976) found that, in ten North Dakota saline seeps, Kochia (Kochia scoparia) and foxtail barley (Hordeum jubatam) are the most common weeds. At lower levels of salinity, they found white prairie aster (Aster ericoides), pigweed (Amaranthus retroflexus) and curly dock (Rumex crispus) were commonly present. These plants decrease in presence as salinity increases. At this point, the predominant plant is

Kochia which disappears entirely as salt crusts form on the surface of the bare soil.

Long (1986) found a similar pattern and was able to correlate the presence of weeds with soil electrical conductivity (EC) readings made with an EM38 electrical conductivity meter. A photo interpretation key with description of photo appearance and corresponding ground conditions (plants, crops and soil) was developed for photointerpreters.

Brown (1976) and Brown et al. (1983) described the characteristics of saline seeps as they develop. Unusual crop growth (unusually luxuriant or lodged), soil surface wetness, salt crystals in soil, stunting of crops and trees, and rank growth of Kochia (Kochia scoparia) or the presence of foxtail barley (Hordeum jubatam) are all listed as indicators of possible saline seeps. A sequence for the visual change in a seep surface as saline seep develops is described.

Electrical and Electromagnetic Methods

A more quantitative approach to ground detection of saline seep is described by Rhoades and Halvorson (1976). They used a four probe (Wenner array) resistivity meter to detect and define salinity in the soil. They concluded that the technique is useful in finding and delineating soil salinity. Cameron et al. (1981) compared the four probe method with the portable EM31 and EM38 electrical conductivity meters to determine their usefulness for mapping soil

salinity. The two meters (EM31 and EM38) induce a current in the soil from which the electrical conductance of the soil is measured. No actual penetration of the soil surface occurs and ease of portability makes the EM38 especially rapid and easy to use in the field. They reported agreement between the three instruments with the EM31 and EM38 electrical conductivity meters being much faster to operate than the four probe method. Wollenhaupt et al. (1986) confirmed Cameron's work and further developed the use of the EM38 in the field. Long (1986) tested the EM38 meter for mapping saline seep and used it as a tool in separating the stages of seep development. This was achieved by comparing horizontal and vertical readings and the ratio between the two.

MATERIALS AND METHODS

Study Area Description

The Soil Conservation Service originally targeted three counties in Northern Montana (Chouteau County, Liberty County, Toole County) for a saline seep survey test (Figure 1). After it appeared that the method tested herein was effective, three more counties were added to the survey area (Teton County, Hill County, Pondera County). The area is bordered by Canada on the north side, the front of the Rocky Mountain overthrust to the west, and a line roughly 10 miles south of the Missouri River to the south and east (Fig. 1).

Most of the region consists of a glacial till plain that overlays Cretaceous shale and sandstone formations. The till plain topography combined with the high salt content of the materials produce good conditions for the formation of saline seeps. Precipitation varies widely over the region. Average annual precipitation is about 12 inches (308 mm) falling mostly during the growing season.

Of the six counties targeted, four have had saline seeps mapped over a part or all of the county, (Teton, Liberty, Chouteau and Toole). The area mapped covers 3.2 million acres. The predominant cropping practice in the region is alternating years of crop and fallow, a dryland water conservation practice.

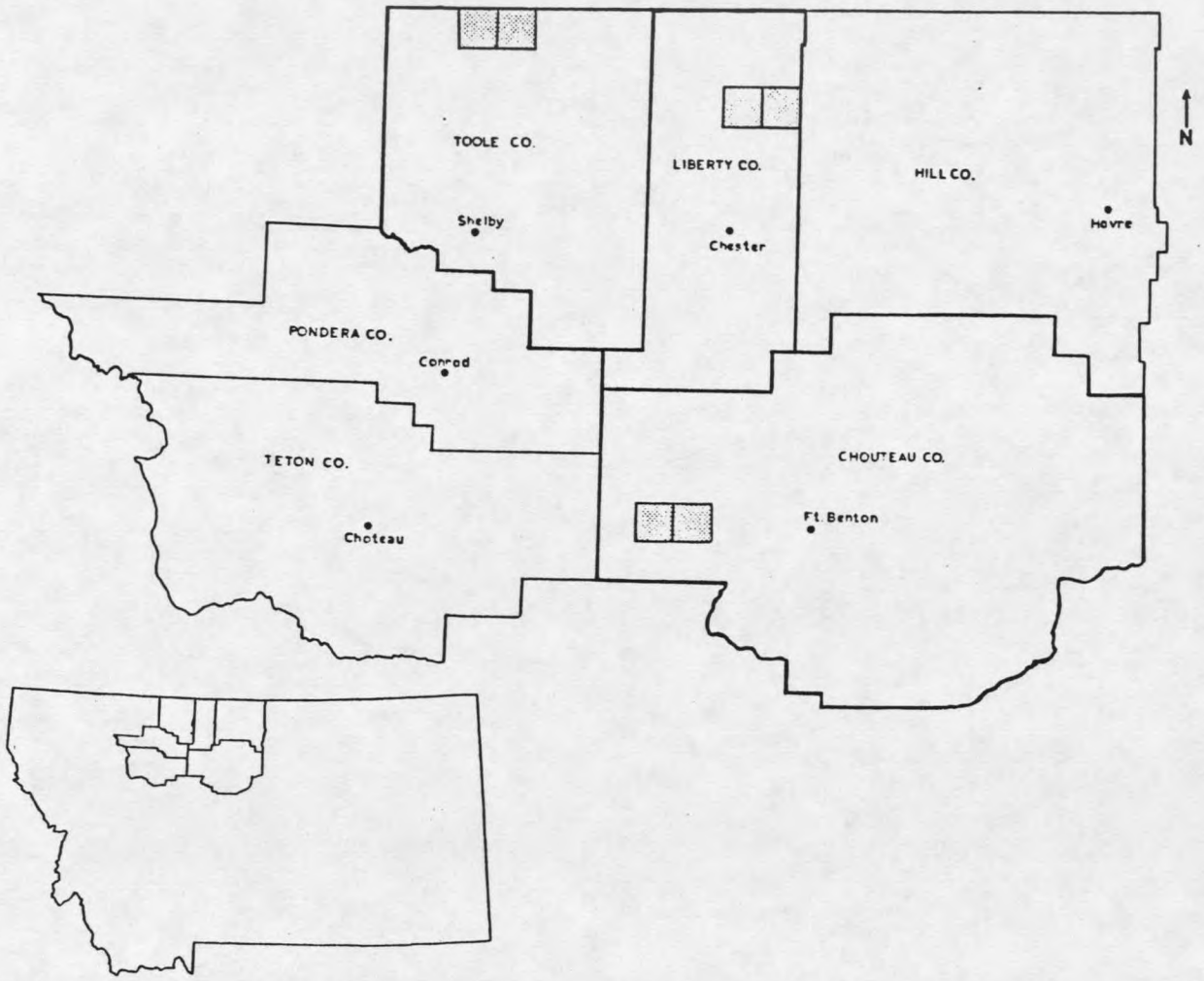


Figure 1. Map showing location of saline seep mapping test area in Northern Montana. The original counties in heavy outline. Actual mapping test areas are shaded.

Aerial Photography

1:32000 scale color infrared (CIR) aerial photography was obtained in June and July of 1986 and 1987. This photography covers all or part of Teton, Liberty, Chouteau and Toole Counties (Fig. 1). A Hasselblad 500 EL-M camera of 70 mm format, equipped with 50 mm lens and a Wratten #15 filter, using Aerochrome type 2443 film was used for all photography obtained.

All photography was obtained from an altitude of about 9,500 feet above sea level from a Cessna Model 172 single engine fixed wing aircraft. Flight lines were laid out along east-west section lines. The lines were altered to traverse the middle of the sections after the first photography was examined, as some difficulty was experienced in locating sections on topographic maps when the imagery was centered on section boundary lines. Field personnel found orientation and locating aerial photos on the United States Geological Survey quad maps much easier after this change was made. Exposures were timed for approximately 30 per cent overlap between exposures. Photographs were taken in the morning between 7:00 a.m. and 10:30 a.m. (daylight saving, Mountain Standard Time) or in the afternoon between 2:30 p.m.and 7:00 p.m. Experience showed that this produced the best imagery color and contrast for use in detecting saline seeps.

Processing of the film was performed by Precision Photo Labs in Dayton, Ohio. After processing, the transparencies

were catalogued and arranged in 8 1/2" x 11" notebooks with index maps to ease the task of locating specific areas of interest. These collections were placed in the district Soil Conservation Service offices of each county once the saline seep interpretations were completed.

Interpretation and Mapping

The original technique, as reported by Long (1986), used 6 cm x 6 cm slide projectors to transfer the interpretations to 8 inches to the mile Agricultural Stabilization and Conservation Service field sheets. For a multi-county project this method is clearly impractical. A total of over 2500 separate maps would have to be produced to cover the entire area. Indexing and storage of this many maps presents a problem of substantial proportions. The Soil Conservation Service agreed to the use of United States Geological Survey topographic quadrangle maps (7 1/2 minute series) as the basis for final maps for field office use. These maps are more convenient for most uses and with a scale of 1:24000, are close to the scale of the original photographs.

Interpretation was done on the original transparencies by overlaying a strip of mylar. The images covered with the mylar were placed under stereo glasses and the corners of the sections and any saline seeps recognized in the section were traced on the mylar. The overlay strips were then placed in an Artograph DB400 projector and the lines transferred to the USGS quadrangle sheets. After an entire quadrangle was

interpreted and transferred, a large sheet of Mylar was overlaid onto the quadrangle sheet. The sheet corners, section corners and the polygons of saline seep were traced and permanently inked onto the overlay sheet. Each overlay sheet was identified with the name of the corresponding USGS quadrangle map.

The classification of each seep was based on the scheme by Long (1986). The Soil Conservation Service tested the photo interpretation key developed by Long (1986) to determine if it could be used in areas outside of that in which it was developed (northern Liberty County). The interpretation key was found to be generally satisfactory. Two slight revisions of the photo interpretation key were made based on problems encountered at the start of the mapping effort (Table 1). A category called "complex seeps" was added to the interpretation key. Some confusion over interpreting complex areas had occurred when applied to the field by newly trained individuals. This was a major source of error in the Liberty County area initially, the problem was corrected by additional field training. The second change was to add the salinized drainage classification for naturally saline flowage ways in the landscape.

Measurement and Compilation

Once the quadrangle map overlay sheets were completed, the areas of the saline seep were measured. Measurement was performed on a video-based computerized measuring device named

the Linear Measuring Set. This system consists of a pair of video cameras connected to a computerized device which can selectively digitize the image produced. The digitized image is then passed to a microcomputer which measures the areas of polygons. There is present in the system a series of programs for image processing and data manipulation which assist in the production of the desired data. The Linear Measuring Set is essentially a very sophisticated electronic planimeter. All measurements were made with the standard land survey section as the basic unit of compilation. All saline seeps within each section were measured and compiled by class of seep (Table 1). Individual stages of saline seep were not separated in the record. This method was adopted because, frequently, individual seeps contain more than one stage of seep development. In this situation, it would appear that more saline seeps existed in a section than actually occur. A separate compilation of the complex saline seep areas was reported due to the large proportion of the total area associated with this situation. The saline seep area measurements were then compiled in a spreadsheet and tabulated separately for each county. Individual reports are prepared for each county (Beyrau et al, in review, 1990).

Table 1. Key to identify saline seep (for crops, weeds and soils in saline seeps using mid-June to mid-July CIR imagery. October, 1988)

PHOTOGRAPH APPEARANCE	GROUND CONDITIONS
BEGINNING SEEPS (STAGE 1)	
CROP. Lush and luxuriant growth occurring in or near various depressional landforms and bordering developing and mature seeps. Appears red in contrast to unaffected crop which is mature and white (mid-July). Or appears darker red than rest of crop which is red (late-June).	Crop yields more than twice that of unaffected areas because of high water table near the root zone.
WEED. Absent due to dense crop cover, cultivation or herbicides.	Average EM38 horizontal and vertical and horizontal readings of 85 and 117 mS/m, respectively. Mean ratio of two values is 0.73. Salts are low, increasing to a peak at shallow depth, then decreasing with further depth.
SOIL. Not visible due to dense crop cover.	
DEVELOPING SEEPS (STAGE 2)	
CROP. Reduced or eliminated crop appears as light red or aqua (see SOIL below for other colors) irregular or semi-circular patches located in or near various depressional landforms and bordering mature seeps.	Crop yields reduced below normal. Individual plants stunted and heads not filled.
WEED. Semi-circular rings or irregular patches of weeds and areas of sod within non-salt encrusted areas. The following two conditions describe weeds:	
1) Kochia visible as bright red patches. Kochia indicates a developing seep when its color is intermixed with bare soil.	1) Principle weed is Kochia. EM38 horizontal reading ranges from 180 to 390 mS/m.

Table 1, (continued)

2) A sod portion consisting of either halophytic or non-halophytic weeds or planted forbes grasses. Sod color is bluish (foxtail barley) or reddish (grasses and forbes mixed.	2) Sod portions contain foxtail barley and other grasses. EM38 horizontal readings between 80 and 370 mS/m.
Developing seeps covered with grasses, mainly foxtail barley, are found inside or adjacent to mature seeps on nearly level terrain.	
SOIL. Aqua, green or gray colored areas of bare soil occur separately or often as partial rings bordering mature seeps (CIR color depends on soil color, exposure, color balance and batch of film).	Salt concentrations are high, increasing to a peak at shallow depth, then decreasing with further depth. Average EM38 horizontal and vertical readings 200 and 235 mS/m, respectively. Mean ratio of the two values is 0.84.

MATURE SEEPS (STAGE 3)

CROP. Absent due to high salt content of soil.

WEED. Irregular patches of weeds within salt encrusted areas.

The following characteristics describe weeds:

1) Pink colored, irregular patches of seablite and samphire within salt encrusted zones. Nuttal alkali grass which is bluish colored may also occur. Rarely are stands large enough to be confused with the signature of foxtail barley.	1) Weeds are seablite, samphire and Nuttal alkali grass. Average EM38 readings both about 363 mS/m.
2) Bright red patches of Kochia intermixed with salt encrusted areas.	2) Flat topography more or less than 2% slope. Weed is Kochia. EM38 horizontal reading is about 300 mS/m.

Table 1 (continued)

SOIL. Encrusted with white salt, often within depressional landforms, but sometimes on hillslopes. Beginning and developing seeps usually border the outer perimeter.	Salts concentration is high at surface decreasing in amount with depth. Average EM38 readings both about 363 mS/m. Mean ratio of the two readings is around 1.0.

COMPLEX SEEPS

Complex seeps are areas having an intermixture of all the characteristics typifying beginning, developing and mature seeps. These are mixed so intimately that the individual stages cannot be separated at the scale of mapping. These areas may include soil that is unaffected by salinity.

SALINIZED DRAINS

Flowage ways in the landscape with naturally occurring saline conditions. May be increased in extent by agriculturally produced seepage. It is not always possible to separate the natural salinity from saline seep.

Field Verification (Testing) of Saline Seep Maps

The mapping was done by SCS field office personnel. A workshop for training SCS personnel was held on December 8 and 9, 1986. Personnel were instructed in the procedures for mapping saline seeps. After this workshop, two townships in each of the three counties were picked to be mapped by SCS field personnel (Figure 1). No examination of the imagery was made in picking the areas to be mapped. They were selected as areas likely to have some saline seeps based on topography and location. All were in the areas photographed in the first season of photography, 1986. The townships were mapped by SCS

personnel in the spring of 1987. Ground investigation of the test mapping areas took place during the latter part of the 1987 growing season. The maps and imagery used by the interpreters were compared with the actual ground location. A classification correctness decision was made on the spot for each mapped saline seep.

One township in each county was selected for ground truthing. This was done because of limitations upon the funding available for ground truthing work. As many of the mapped saline seeps as possible were examined in the time allowed for field work (about one week in each county).

An exception to this occurred in Liberty County. The camera shutter failure produced strips of imagery that were blank in part or entirely for 38 of the sections in the test area. Saline seeps were mapped in the remaining 34 partially or completely photographed sections. Due to the fact that the saline seeps mapped in Liberty County were thus scattered over two townships rather than in one township, a slightly smaller number of sites were visited in the time available.

Over 200 mapped seeps were examined in the three counties. All classes and a wide range of sizes were included.

The major thrust of the ground truth examination was to determine if the maps produced by newly trained interpreters were reliable. The types of errors that could occur in this type of work are: 1) errors of omission, 2) errors of

commission and 3) errors of extent. An error of omission is the failure to detect the condition sought when it is present. In this study, that would be not detecting a saline seep that exists in a given location. Errors of commission are the identifying of saline seeps that do not exist. Errors of extent involve the incorrect delineation of the area covered by saline seep. In the ground truthing of the maps, errors of commission were the primary errors examined. Errors of omission are very difficult to detect on the ground, especially when the fields in question are fallow. A few errors of this type were detected in the course of the ground investigations. Errors of extent are not dealt with in this work due to time limitations for the field work. It was found in a subsidiary study performed at the request of the SCS, that annual changes in extent of saline seeps occur, probably due to precipitation variations, from year to year (Long, 1988).

The EM38 Electrical Conductivity Meter

The Geonics Limited EM-38 Electrical Conductivity meter was used to measure the electrical conductivity (EC) of the soils. This device electromagnetically induces an electrical current flow in the soil that is proportional to the amount of salt present. The readings made with this device reflect the cumulative contribution of soil electrical conductivity to some depth in the soil. When the device is laid on its side (horizontal position) the measurement reflects the EC to about

0.5 m depth. When held upright (vertical position), the readings reflect the cumulative EC to about 1.0 m depth. The horizontal position reading gets about 44 per cent of its reading from the first 30 cm of soil depth. The vertical position gets only 15 percent of its reading from the same depth. As a result the horizontal position is more sensitive than the vertical position (Long, 1986; Corwin and Rhoades, 1982; Wollenhaupt et al, 1986).

These two factors, the horizontal and vertical readings, and the ratio of these two factors were used to determine if the mapped unit of saline seep had an EC and EC ratio (EC Vertical/EC Horizontal) that corresponded to the claimed stage of seep development.

Accuracy Criteria

Correctness of identification of a saline seep was determined on the basis of crop condition, presence or absence of halophytic weeds, soil surface appearance and electrical conductivity readings taken with an EM38 conductivity meter. The criteria used to define each saline seep class are in Table 1. Each seep was examined visually on the ground and compared against the criteria listed in Table 1. A determination was then made as to the reason for any incorrect identifications. At the same time, readings were taken with the EM38 to determine the EC of the site. On most sites EC readings were taken along transects across the entire width of the area indicated on the SCS produced saline seep maps. In

most cases, one transect was sufficient to determine whether the mapped seep was correctly identified.

RESULTS AND DISCUSSION

Quality of Photography

During the initial year of photography, June and July of 1986, the camera's shutter mechanism failed after several hundred photographs were taken. As a result, the quality of the images produced varied widely among the three test areas (Table 2). The best quality images were the transparencies from the Toole Co. test area. The images from Liberty quality were the worst quality. The Chouteau Co. images were usable but suffered from some overexposure. All of the transparencies were inspected when returned from the processor. Changes in the daily flying periods were instituted when it was noted that exposures around mid-day tended to be overexposed due to specular reflections from the ground (first observed in the Chouteau Co. images). This single change corrected the overexposure problem. The failure of the camera shutter occurred soon thereafter and work ceased for the season. Areas where overexposure or blurring occurred were rephotographed the following year. Funding and time limitations forced the use of the original photography, good or bad, in this test.

Table 2. Quality of photography for Liberty, Chouteau, and Toole County test areas.

County	Exposure	Image Quality	Overall Quality
Liberty	Variable	Blurred images Indistinct detail	Poor
Chouteau	Minor overexposure	Light areas faded Images sharp	Fair
Toole	Correct	Good color Images sharp	Good

Examination of Mapped Saline Seep

The results for each county are reported in Tables 2, 3, 4 & 5. A detailed comparison of the mapping and the ground truth is provided in Tables 4 and 5.

The causes of saline seep mapping inaccuracy varied in the three counties. The major causes were directly related to image quality. Poor image quality (Table 2) resulted in many saline seep identification errors (Table 3). The poorest accuracy (34% $\pm$ 12.1%) was achieved in Liberty county where image quality was poorest. Where better image quality existed (Chouteau Co. & Toole Co.), better identification accuracy was obtained (61%$\pm$ 12.1% and 79% $\pm$ 9.7% respectively). In Liberty county the area of poor image quality was rephotographed the following year and new, high quality imagery obtained. The area was remapped and the results compared to the original mapping ground truth. Twenty two mapped seeps that had been visited within the original mapping area were mapped again in

Table 3. Confidence intervals for correctness of identification of saline seep in three selected townships in Northern Montana.

	COUNTY AND TOWNSHIP		
	Liberty T36N R6E & R7E	Chouteau T24N R5E	Toole T37N R2W
# of trials	59	62	67
# of successes	20	38	53
proportion of successes	.338	.613	.791
Confidence intervals (1)	34% ±12.1%	61% ±12.1%	79% ±9.7%

(1) 95% confidence interval when,

$P_{c.i.} = F \pm Z_{a/2} * SQRT[(F(1-F))/N]$

where

$P_{c.i.}$ = proportional confidence interval
$Z_{a/2} = 1.96$
F = Proportion of successes
N = Number of trials
a = .05

the remapped area (Table 7). Nineteen seeps coincided between the two maps and the ground truth investigation (Table 6). The remaining three were incorrectly identified and no evidence of saline seep was found on the ground in these locations. Table 6 shows eighteen of the nineteen seeps mapped by the interpreter were correctly identified giving an overall accuracy of 94.7% ± 10%*. The only error in the remapped area was identifying a stage 2 seep at a location where no seep was found (Table 7).

* - confidence interval calculated by method given in Table 3.

Table 4. Correctness of identification of saline seep development stage in three test areas in Liberty, Chouteau and Toole counties of Montana.

Liberty County

	STAGE					
	1	2	3	CPX[1]	SD[2]	TOTAL
CORRECT	1	11	6	2	0	20
INCORRECT	0	14	7	18	0	39
TOTAL	1	25	13	20	0	59

Chouteau County

	STAGE					
	1	2	3	CPX[1]	SD[2]	TOTAL
CORRECT	19	9	8	0	2	38
INCORRECT	11	7	6	0	0	24
TOTAL	30	16	14	0	2	62

Toole County

	STAGE					
	1	2	3	CPX[1]	SD[2]	TOTAL
CORRECT	20	16	9	8	0	53
INCORRECT	3	2	8	1	0	14
TOTAL	23	18	17	9	0	67

1 - CPX = saline seep complex (see Table 1 for definition)
2 - SD = salinized drainage (see Table 1 for definition)

Table 5. Comparison between ground truth and interpreter mapping saline seeps for test areas in Liberty, Chouteau and Toole Counties, Montana.

		Interpreter Mapping STAGE							GROUND TRUTH TOTAL
		Unm[1]	NAF[2]	1	2	3	CPX	SD	
Liberty Co. Ground Truth	NAF	0	0	0	10	4	17	0	31
	1	0	0	1	4	2	0	0	7
	2	1	0	0	11	1	1	0	14
	3	1	0	0	0	6	0	0	7
	CPX[3]	0	0	0	0	0	2	0	2
	SD[4]	0	0	0	0	0	0	0	0
INTERPRETER TOTAL		2	0	1	25	13	20	0	61

		Interpreter Mapping STAGE							GROUND TRUTH TOTAL
		Unm[1]	NAF[2]	1	2	3	CPX	SD	
Chouteau Co. Ground Truth	NAF	0	0	10	4	4	0	0	18
	1	0	0	19	2	0	0	0	21
	2	0	0	1	9	2	0	0	12
	3	0	0	0	1	8	0	0	9
	CPX[3]	0	0	0	0	0	0	0	0
	SD[4]	0	0	0	0	0	0	2	2
INTERPRETER TOTAL		0	0	30	16	14	0	2	62

		Interpreter Mapping STAGE							GROUND TRUTH TOTAL
		Unm[1]	NAF[2]	1	2	3	CPX	SD	
Toole Co. Ground Truth	NAF	0	0	0	1	1	3	0	5
	1	0	0	20	1	3	1	0	25
	2	2	0	2	16	5	0	0	25
	3	2	0	1	0	9	0	0	12
	CPX[3]	0	0	0	0	0	8	0	8
	SD[4]	0	0	0	0	0	0	0	0
INTERPRETER TOTAL		4	0	23	18	18	12	0	75

1 - Unm = Unmapped saline seep-missed by interpreter.
2 - NAF = No saline seep found on site mapped.
3 - CPX = Complex saline seep (described in Table 1).
4 - SD = Salinized drainage (described in Table 1).

The results of the second mapping reflects the improved quality of the imagery and the increasing skill level of the interpreter. To separate the contribution of each factor to the overall increase in accuracy is difficult. Based on the results in Toole county, the interpreter skill increase may contribute between 5 and 15 per cent of the accuracy increase.

Table 6. Correctness of identification of saline seep remapping in part of the Liberty Co. test area.

	STAGE					
	1	2	3	CPX[1]	SD[2]	TOTAL
CORRECT	7	2	3	5	1	18
INCORRECT	0	1	0	0	0	1
TOTAL	7	3	3	5	1	19

1 - CPX = saline seep complex (see Table 1 for definition)
2 - SD = salinized drainage (see Table 1 for definition)

Table 7. Comparison of ground truth and interpreter mapping in remapped part of Liberty Co. test area.

		Interpreter mapping							
	Stage	Unm[1]	NAF[2]	1	2	3	CPX	SD	TOTAL
	NAF	0	3	0	1	0	0	0	4
GROUND	1	0	0	7	0	0	0	0	7
TRUTH	2	0	0	0	2	0	0	0	2
	3	0	0	0	0	3	0	0	3
	CPX[3]	0	0	0	0	0	5	0	5
	SD[4]	0	0	0	0	0	0	1	1
TOTAL		0	3	7	3	3	5	1	22

1 - Unm = Unmapped saline seep--missed by interpreter.
2 - NAF = No saline seep found on site mapped.
3 - CPX = Complex saline seep (defined in Table 1).
4 - SD = Salinized drainage (defined in Table 1).

Sources Of Mapping Error

The causes of error in identifying stages of saline seeps are diverse. Each stage has its own set of error producing conditions.

Beginning seeps or stage 1 seeps are typified by very lush growth of vegetation. In most misidentified beginning seeps (Table 5), the areas accumulated water during the early part of the growing season. The result was relatively lush growth compared to the surrounding area. Similar topographically low areas are the sites where saline seeps often occur. The difference between the two is whether the water comes from below (rising water table) in the case of a beginning saline seep or is due to overland flow from surrounding areas. On an aerial photo it is difficult or impossible to distinguish which situation prevails. Thus, identification of beginning saline seeps will probably always be imperfect.

Developing seeps or stage 2 seeps are typified by a thinning or decrease in crop growth due to increasing soil salinity near the surface. But, other factors can also cause thin crop stands. In Liberty Co., Natrargid soils were frequently mapped as developing seeps or complex seeps, especially when poor quality aerial photographs were used. Field examination of the incorrectly mapped saline seeps revealed that the topographic location of the "complexes" was one in which seep was unlikely to occur (tops of upland

areas). This misidentification problem was corrected and has not recurred. Other causes of error included a variety of agronomic problems or soil conditions which affected plant growth.

Mature or stage 3 seeps are areas in which all crops are gone and a crust of salt occurs. The most common error in identifying a mature seep was mistaking a light colored bare soil for salt crust. Usually this occurred with soils such as the Nisshon (fine, montmorillonitic, frigid Typic Albaqualfs) series. This error was most frequent where the aerial photos were slightly overexposed. These sites frequently develop smooth crusts after wetting. Combined with a natural low fertility, this condition can produce an appearance similar to a mature seep, especially if Kochia is growing in the area.

Two other conditions, extreme lodging and foxtail barley infestations, resembled mature seeps on the air photos. Extreme lodging of wheat (1.5 m to 2.0 m tall) occurred in one location in Toole Co. On the airphotos, this site appeared very similar to a salt crust due to specular reflection of sunlight from the stems of the prostrate wheat plants. Foxtail barley (Hordeum jubatum) is a halophytic plant frequently found in developing seeps and around the edges of mature seeps. Due to its early season maturity, it was usually straw-colored on the ground when the imagery was acquired. On the aerial photographs, foxtail barley took on an appearance very similar to that of salt crust. A yellowish

tinge to the image color was noted in some cases. The result was that a developing seep was misidentified as a mature seep.

First priority was given to examining the largest possible number of seeps mapped by the interpreters. While examining these areas, a lookout was kept for seeps that were not detected by interpreters. Omission errors had several causes. The most prominent of these was the difficulty of detecting beginning and developing seeps in fallow areas. The presence of halophytic weeds and salt crusts were almost the only reliable indicators that a ground observer can use. In fallow areas, weeds may not be present due to tillage or spraying of herbicides.

Saline seeps occurring in rangeland areas are similarly difficult to detect. The grasses common in salt affected areas frequently make the detection of these areas problematical. At most of rangeland sites, the CIR transparencies revealed a different image pattern from that described in Table 1. Interpreters did locate several of these sites. However, the main effort here was devoted to detecting saline seeps in cropland areas.

A few unmapped saline seeps were found in the test areas. Table 5 shows 4 in Toole Co. and 2 in Liberty Co. Mostly, they occurred in areas that were fallow in the year of photography. This is one shortcoming of the system for which there is no satisfactory solution. In many cases, it is possible to extrapolate boundaries across fallow areas between

strips of crop where saline seep effects are observed. Rephotographing the same area the following year would eliminate this problem. Most fallow areas would be planted to crops the following year.

Errors tended to decrease as interpreters increased in experience. The remapped area in Liberty Co. had an increase of 300% in accuracy between the first and second attempts. Most of the improvement was a result of improved quality of photography, but some of it was also due to the increase in skill of the interpreter.

Consistency of Measurement

An opportunity to test the consistency of the mapping technique occurred when the same quadrangle was mapped twice by the same interpreter. The Shonkin quadrangle in Chouteau Co. was mapped with overlapping imagery taken in successive years (1986 and 1987). The LMS was used to measure 95 saline seep units on both maps (Appendix D). Table 8 shows that the differences between the two maps were small. There are however twelve instances in which a seep mapped on one set of images was not found in the corresponding location on the other images. In most cases, the areas were small (<5 acres), but one area on the later images was 63.86 acres in extent (C270 in T22N R8E Sec 8). This problem appears to be a result of the somewhat overexposed appearance of the earlier photos making the seep area hard to detect.

Table 8. Comparison of two separate mappings of saline seeps on the Shonkin Quadrangle using different years'imagery (1986 &1987).

	Total area	Mean area	STD.[1] dev.
	----------	acres	----------
SHONKIN MAP,1986	1241.82	13.65	17.37
SHONKIN MAP,1987	1274.34	14.32	18.12
difference	32.52	.67	
% difference	2.62%	4.91%	

1- STD. = Standard deviation from the mean area.

The Linear Measuring Set (LMS) was also tested for the repeatability of measurements. Forty-seven seep units of varying size were measured. After all 47 areas were measured once, the LMS was shut off and left for a period of time ranging from 30 minutes to 18 hours. The machine was then turned on, the scale reset and the 47 areas measured again.

Table 9. Comparison of 6 measurements of 47 saline seep units taken with the Linear Measuring Set.

	Max	Min	Mean	STD.[1]	%STD.[2]
	----------acres----------				
Total area (acres)	477.9	451.9	465.6	8.1	1.73%
% STD of area of individual polygon measurements	9.46	.76	2.49	1.82	

1 STD.= Standard Deviation.
2 %STD.= Per cent Standard Deviation

The process was repeated six times. The results were then analyzed for variability (Appendix E and Table 9). The linear measuring set gave a high degree of repeatability in measurement. The mean total area measured was 465.6 acres. The standard deviation was 8.1 acres or 1.73% and the individual measurements varied by a mean of 2.49%. Errors of interpreters are much larger than the errors introduced in the measurement process.

CONCLUSIONS

1. The saline seep mapping technique reported by Long gave an accuracy level of about 80% when properly trained interpreters were supplied with high quality aerial imagery.
2. Similarities between the air photo appearance of non-saline run-in areas and beginning saline seep areas make their separation on airphotos problematical unless beginning seeps are adjacent developing or mature seeps.
3. The mechanical process of measuring areas of the interpreted imagery polygons produced consistent measurements of the areas of saline seeps.
4. Early errors in the identification of saline seeps in Liberty County were largely corrected by additional training of interpreters in the field.

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APPENDICES

APPENDIX A

Toole Co. Saline Seep
Ground Truth Results

Table 10. Toole County saline seep ground truth results.

Twnshp & Rnge	Sect.	Mapped stage	Correct Y/N	Topo. post[1]	Vegetation[2]	EM38 Horz.[3]	EM38 Vert.[3]
T37N R2W	19C	CPX	Y	DRAIN	2R-BARLEY	160	100
T37N R2W	28A	CPX	Y	DRAIN	FALLOW	160	90
T37N R2W	36C	CPX	Y	SDSLP	SORGHUM	100	60
T37N R2W	29B	CPX	Y	SDSLP	NAT. GRSS	480	600
T37N R2W	10A	1	N	DRAIN	FLAX	300	320
T37N R2W	8A	1	Y	DRAIN	FLAX	25	10
T37N R2W	18A	1	Y	DRAIN	FALLOW	66	40
T37N R2W	21C	1	Y	SDSLP	SWT CLVR	190	170
T37N R2W	1C	1	Y	UPL-L	FALLOW	36	18
T37N R2W	8B	1	Y	RUN-IN	FALLOW	58	32
T37N R2W	1D	1	Y	UPLAND	FALLOW	36	18
T37N R2W	9C	1	Y	DRAIN	WHEAT	68	84
T37N R2W	3A	1	Y	DRAIN	WHEAT	35	20
T37N R2W	4A	1	Y	DRAIN	WHEAT	30	15
T37N R2W	21B	1	Y	RUN-IN	SWT CLVR	80	60
T37N R2W	3D	1	Y	DRAIN	FALLOW	130	154
T37N R2W	1E	1	Y	UPLAND	SWT CLVR	22	14
T37N R2W	9A	1	Y	DRAIN	WHEAT	17	8
T37N R2W	1A	1	Y	SDSLP	SWT CLVR	17	6
T37N R2W	1B	1	Y	SDSLP	WHEAT	26	21
T37N R2W	30A	1	Y	RUN-IN	2R-BARLEY	150	110
T37N R2W	19B	1	Y	DRAIN	WHEAT	56	32
T37N R2W	20A	1	Y	RUN-IN	FALLOW	29	15

Table 10 (continued)

Twnshp & Rnge	Sect.	Mapped stage	Correct Y/N	Topo. post[1]	Vegetation[2]	EM38 Horz.[3]	EM38 Vert.[3]
T37N R2W	30B	2	Y	DRAIN	2R-BARLEY	NR	NR
T37N R2W	36D	2	Y	DRAIN	FALLOW	250	200
T37N R2W	19A	2	Y	DRAIN	WHEAT	300	280
T37N R2W	2B	2	Y	RUN-IN	2R-BARLEY	150	120
T37N R2W	11B	2	Y	RUN-IN	2R-BARLEY	580	700
T37N R2W	36A	2	Y	DRAIN	FALLOW	300	250
T37N R2W	17A	2	Y	DRAIN	FALLOW	290	250
T37N R2W	19D	2	Y	DRAIN	NAT GRSS	680	740
T37N R2W	4B	2	Y	LK BD	NAT GRSS	50	20
T37N R2W	1F	2	Y	DRAIN	WHEAT	170	150
T37N R2W	3C	3	N	DRAIN	WHEAT	20	9
T37N R2W	9B	3	N	DRAIN	WHEAT	34	20
T37N R2W	2A	3	N	DRAIN	2R-BARLEY	250	200
T37N R2W	2C	3	Y	RUN-IN	2R-BARLEY	350	350

1 - Topographic position: DRAIN = drainways, stream channels, etc., SDSLP = sideslope, LK BD = Lake bed, RUN-IN = area of water ponding, potholes. UPLAND, UPL = hilltop, plateau area, etc.

2 - SWT CLVR = Sweet clover, NAT GRSS = Grassland, 2R-BARLEY = 2-row barley, FALLOW = no crop, bare ground.

3 - NR = No readings possible due to interference from power lines.

4 - UNM = Unmapped

APPENDIX B

Liberty Co. Saline Seep
Ground Truth Results

Table 11. Liberty Co. saline seep ground truth results.

Twnshp & Rnge	sect	Mapped stage	Correct Y/N	Topo. post[1]	Vegetation[2]	EM38 Horz.	EM38 Vert.
T36N R6E	1A1	2	Y	RUN-IN	2R-BARLEY	280	220
T36N R6E	1A2	3	Y	RUN-IN	2R-BARLEY	280	220
T36N R6E	1B	2	Y	RUN-IN	2R-BARLEY	200	180
T36N R6E	1C	2	Y	RUN-IN	2R-BARLEY	200	180
T36N R6E	1D	CPX	N	UPLAND	2R-BARLEY	40	13
T36N R6E	2A1	2	Y	DRAIN	NAT. GRS.	80	40
T36N R6E	2A2	3	Y	DRAIN	NAT. GRS.	200	300
T36N R6E	2B	2	Y	DRAIN	2R-BARLEY	120	100
T36N R6E	2C1	1	Y	DRAIN	FALLOW	25	10
T36N R6E	2C2	3	N	DRAIN	FALLOW	40	30
T36N R6E	2D	CPX	N	UPLAND	WHEAT	30	18
T36N R6E	3B	CPX	N	SDSLP	WHEAT	25	20
T36N R6E	3A	3	UNM[3]	SDSLP	WHEAT	250	450
T36N R7E	2A	CPX	N	UPLAND	BARLEY	35	20
T36N R7E	2B1	2	N	RUN-IN	2R-BARLEY	15	30
T36N R7E	2B2	3	N	RUN-IN	2R-BARLEY	50	80
T36N R7E	2C	2	N	RUN-IN	FALLOW	50	22
T36N R7E	3A	CPX	N	UPLAND	WHEAT	50	25
T36N R7E	3B	CPX	N	UPLAND	WHEAT	45	30
T36N R7E	3C	CPX	N	UPLAND	BARLEY	70	50
T36N R7E	5A1	2	N	UPLAND	NAT. GRS.	10	3
T36N R7E	5A2	3	N	UPLAND	NAT. GRS.	18	6
T36N R7E	5B	2	N	UPLAND	WHEAT	44	22

Table 11 (continued)

Twnshp & Rnge	sect	Mapped stage	Correct Y/N	Topo. post[1]	Vegetation[2]	EM38 Horz.	EM38 Vert.
T36N R7E	5C	2	N	UPLAND	WHEAT	44	22
T36N R7E	5D	CPX	N	UPLAND	WHEAT	38	20
T36N R7E	13A1	2	Y	SDSLP	NAT. GRS.	200	250
T36N R7E	13A2	3	Y	SDSLP	NAT. GRS.	200	250
T36N R7E	13B	CPX	Y	UPLAND	FALLOW	70	40
T36N R7E	13C	CPX	Y	UPLAND	FALLOW	65	25
T36N R7E	14C	3	Y	RUN-IN	FALLOW	220	190
T36N R7E	14A	2	N	RUN-IN	FALLOW	120	80
T36N R7E	14B	3	N	RUN-IN	FALLOW	120	80
T36N R7E	14D	CPX	N	UPLAND	WHEAT	50	20
T36N R7E	15A	CPX	N	UPLAND	SAFFLOWER	80	40
T36N R7E	16A	2	N	RUN-IN	WHEAT	42	20
T36N R7E	16B	2	N	RUN-IN	WHEAT	30	12
T36N R7E	16C	CPX	N	RUN-IN	WHEAT	30	12
T36N R7E	23F1	2	Y	DRAIN	2R-BARLEY	120	90
T36N R7E	23F2	3	Y	DRAIN	2R-BARLEY	120	90
T36N R7E	23D	2	Y	RUN-IN	2R-BARLEY	180	110
T36N R7E	23E	2	Y	RUN-IN	2R-BARLEY	180	110
T36N R7E	23B	2	N	UPLAND	2R-BARLEY	60	30
T36N R7E	23C	3	N	UPLAND	2R-BARLEY	60	30
T36N R7E	23A	2	N	UPLAND	2R-BARLEY	60	30
T36N R7E	24C	CPX	N	UPLAND	2R-BARLEY	90	40
T36N R7E	24A	2	Y	UPLAND	2R-BARLEY	90	65

Table 11 (continued).

Twnshp & Rnge	sect.	Mapped stage	Correct Y/N	Topo. post[1]	Vegetation[2]	EM38 Horz.	EM38 Vert.
T36N R7E	24B	CPX	N	UPLAND	2R-BARLEY	70	35
T36N R7E	25C	CPX	N	UPLAND	WHEAT	62	25
T36N R7E	25A1	2	N	RUN-IN	WHEAT	32	40
T36N R7E	25A2	3	N	RUN-IN	WHEAT	32	40
T36N R7E	25A3	2	N	RUN-IN	WHEAT	25	35
T36N R7E	25B1	2	N	RUN-IN	WHEAT	32	40
T36N R7E	25B2	2	N	RUN-IN	WHEAT	32	46
T36N R7E	25D	2	UNM[3]	RUN-IN	WHEAT	130	100
T36N R7E	26A1	2	N	RUN-IN	STUBBLE	40	20
T36N R7E	26A2	3	N	RUN-IN	FALLOW	60	50
T36N R7E	26C	CPX	N	UPLAND	WHEAT	60	40
T36N R7E	27A	2	N	UPLAND	WHEAT	35	20
T36N R7E	27B	2	Y	UPLAND	WHEAT	60	50
T36N R7E	30A	2	N	UPLAND	FALLOW	20	13
T36N R7E	30B	3	N	UPLAND	FALLOW	20	20

1 - Topographic position: DRAIN = drainways,stream channels, etc., SDSLP = sideslope, LK BD = Lake bed, RUN-IN = area of water ponding, potholes. UPLAND, UPL = hilltop, plateau area, etc.

2 - SWT CLVR = Sweet clover, NAT GRSS = Grassland, 2R-BARLEY = 2-row barley, FALLOW = no crop, bare ground.

3 - UNM = Unmapped

APPENDIX C

Chouteau Co. Saline Seep
Ground Truth Results

Table 12. Chouteau Co. saline seep ground truth results.

Twnshp & Rnge	Sect	Mapped stage	Correct Y/N	Topo. post[1]	Vegetation[2]	EM38 Horz.[3]	EM38 Vert.[3]
T24N R5E	7A	1	Y	DRAIN	WHEAT	15	8
T24N R5E	7B	1	Y	DRAIN	WHEAT	15	8
T24N R5E	8A	2	Y	UPLAND	WHEAT	130	60
T24N R5E	10A	1	Y	RUN-IN	FALLOW	50	38
T24N R5E	11A	1	Y	DRAIN	NAT. GRSS.	25	15
T24N R5E	12A	1	Y	DRAIN	NAT. GRSS.	25	15
T24N R5E	12B	3	N	SDSLP	NAT. GRSS.	25	15
T24N R5E	12B	1	Y	DRAIN	NAT. GRSS.	25	15
T24N R5E	13A	2	N	RUN-IN	FALLOW	25	15
T24N R5E	14A	1	Y	DRAIN	FALLOW	10	8
T24N R5E	14B	1	Y	DRAIN	FALLOW	10	8
T24N R5E	15A	1	N	DRAIN	NAT. GRSS.	16	10
T24N R5E	15B	1	Y	DRAIN	2R-BARLEY	16	8
T24N R5E	19A	1	Y	RUN-IN	WHEAT	35	25
T24N R5E	20A	1	Y	DRAIN	SAFFLOWER	35	30
T24N R5E	20B1	2	Y	DRAIN	SAFFLOWER	150	50
T24N R5E	20B2	3	Y	DRAIN	SAFFLOWER	180	90
T24N R5E	21A1	1	N	DRAIN	2R-BARLEY	200	175
T24N R5E	21A2	2	Y	DRAIN	2R-BARLEY	500	400
T24N R5E	21B1	1	N	DRAIN	NAT.GRSS.	500	175
T24N R5E	21B2	2	Y	DRAIN	NAT.GRSS.	500	175
T24N R5E	21C1	1	Y	DRAIN	NAT.GRSS.	200	175

Table 12 (continued)

Twnshp & Rnge	sect	Mapped stage	Correct Y/N	Topo. post[1]	Vegetation[2]	EM38 Horz.[3]	EM38 Vert.[3]
T24N R5E	21C2	2	Y	DRAIN	NAT. GRSS.	350	300
T24N R5E	21C3	3	Y	DRAIN	NAT.GRSS.	350	450
T24N R5E	21D1	1	Y	RUN-IN	FALLOW	35	17
T24N R5E	21D2	1	Y	RUN-IN	WHEAT	35	17
T24N R5E	23A	1	Y	DRAIN	WHEAT	20	12
T24N R5E	23B	1	Y	DRAIN	WHEAT	20	12
T24N R5E	28A	1	Y	RUN-IN	NAT.GRSS.	40	10
T24N R5E	28B1	1	Y	RUN-IN	2R-BARLEY	100	80
T24N R5E	28B2	2	Y	RUN-IN	2R-BARLEY	300	220
T24N R5E	28C	3	Y	RUN-IN	NAT.GRSS.	300	280
T24N R5E	29D	1	N	UPLAND	SAFFLOWER	10	3
T24N R5E	29E1	1	N	UPLAND	FALLOW	20	15
T24N R5E	29E2	2	N	UPLAND	FALLOW	20	15
T24N R5E	29E3	3	N	UPLAND	FALLOW	20	15
T24N R5E	29C	1	N	UPLAND	SAFFLOWER	25	12
T24N R5E	29B	2	N	UPLAND	SAFFLOWER	30	18
T24N R5E	30A	1	Y	DRAIN	2R-BARLEY	50	20
T24N R5E	30B	1	Y	RUN-IN	2R-BARLEY	40	10
T24N R5E	31A1	1	Y	DRAIN	NAT.GRSS.	100	80
T24N R5E	31A2	2	Y	DRAIN	NAT.GRSS.	350	250
T24N R5E	31A3	3	Y	DRAIN	NAT.GRSS.	600	600
T24N R5E	31B1	2	Y	FTSLP	NAT.GRSS.	350	250
T24N R5E	31B2	3	Y	FTSLP	NAT.GRSS.	350	350

Table 12 (continued)

Twnshp & Rnge	sect	Mapped stage	Correct Y/N	Topo. post[1]	Vegetation[2]	EM38 Horz.[3]	EM38 Vert.[3]
T24N R5E	31C	1	N	FTSLP	NAT.GRSS.	250	250
T24N R5E	30C	2	N	RUN-IN	NAT.GRSS.	40	10
T24N R5E	32D	1	Y	UPLAND	FALLOW	100	150
T24N R5E	32A1	2	Y	DRAIN	NAT.GRSS.	200	200
T24N R5E	32A2	3	Y	DRAIN	NAT.GRSS.	350	300
T24N R5E	32B	2	Y	DRAIN	NAT.GRSS.	90	40
T24N R5E	32C	3	Y	DRAIN	NAT.GRSS.	350	200
T24N R5E	33A1	2	N	UPLAND	FALLOW	60	30
T24N R5E	33A2	3	N	UPLAND	FALLOW	60	30
T24N R5E	33A3	3	N	UPLAND	FALLOW	60	30
T24N R5E	34	SD	Y	DRAIN	NAT.GRSS.	NR	NR
T24N R5E	35A1	1	Y	DRAIN	NAT.GRSS.	20	10
T24N R5E	35A2	2	Y	DRAIN	NAT.GRSS.	80	50

1 - Topographic position: DRAIN = drainways,stream channels, etc., SDSLP = sideslope, LK BD = Lake bed, RUN-IN = area of water ponding, potholes. UPLAND, UPL = hilltop, plateau area, etc.

2 - SWT CLVR = Sweet clover, NAT GRSS = Grassland, 2R-BARLEY = 2-row barley, FALLOW = no crop, bare ground.

3 - NR = No readings possible due to interference from power lines.

APPENDIX D

Comparison of 2 Mappings of One Site

Table 13. Comparison of two mappings of the same area by one observer using imagery taken in successive years (Map 1, 1986 & Map 2, 1987).

Township Range & Section	Seep type	Shonkin Quadrangle duplicate map 1	map 2	Difference in mapped area
		----------acres----------		
T22N R8E SEC 1	C370	2.90	2.91	0.01
T22N R8E SEC 1	2	3.02	8.21	5.19
T22N R8E SEC 1	1	6.01	0.00	6.01
T22N R8E SEC 3	SD	8.51	10.56	2.05
T22N R8E SEC 4	SD	2.63	2.33	0.30
T22N R8E SEC 4	2	11.22	10.97	0.25
T22N R8E SEC 5	C270	59.97	63.46	3.49
T22N R8E SEC 5	C250	12.06	15.01	2.95
T22N R8E SEC 5	C250	2.71	unm[1]	2.71
T22N R8E SEC 8	1	4.26	4.30	0.04
T22N R8E SEC 8	2	51.28	5.80	45.48
T22N R8E SEC 8	3	3.17	2.64	0.53
T22N R8E SEC 8	C150	14.42	14.12	0.30
T22N R8E SEC 8	C250	10.31	10.96	0.65
T22N R8E SEC 8	C460	59.67	57.77	1.90
T22N R8E SEC 8	2	1.64	unm[1]	1.64
T22N R8E SEC 8	C270	unm[1]	63.86	63.86
T22N R8E SEC 9	1	12.63	9.10	3.53
T22N R8E SEC 9	2	16.67	23.30	6.63
T22N R8E SEC 9	3	1.12	1.11	0.01
T22N R8E SEC 11	1	6.37	6.50	0.13
T22N R8E SEC 11	2	0.94	1.11	0.17

Table 13 - (continued)

Township Range & Section	Seep Stage	Shonkin Quadrangle duplicate map 1	map 2	Difference in mapped area
		----------acres----------		
T22N R8E SEC11	SD	1.15	1.21	0.06
T22N R8E SEC12	1	40.54	42.37	1.83
T22N R8E SEC12	2	51.17	56.24	5.07
T22N R8E SEC12	3	8.05	5.52	2.53
T22N R8E SEC12	SD	4.91	4.97	0.06
T22N R8E SEC13	1	6.91	6.88	0.03
T22N R8E SEC13	2	49.29	59.50	10.21
T22N R8E SEC13	3	2.94	3.63	0.69
T22N R8E SEC13	C140	1.26	1.47	0.21
T22N R8E SEC13	C220	7.63	8.40	0.77
T22N R8E SEC13	SD	2.37	unm[1]	2.37
T22N R8E SEC14	2	13.01	11.91	1.10
T22N R8E SEC16	3	4.24	3.75	0.49
T22N R8E SEC17	2	5.48	4.93	0.55
T22N R8E SEC17	3	1.63	1.88	0.25
T22N R8E SEC17	C460	3.68	4.97	1.29
T22N R8E SEC17	C220	79.37	79.36	0.01
T22N R8E SEC20	2	43.21	44.52	1.31
T22N R8E SEC20	3	5.98	4.55	1.43
T22N R8E SEC21	1	8.11	9.57	1.46
T22N R8E SEC21	2	32.54	33.61	1.07
T22N R8E SEC21	3	6.23	9.61	3.38
T22N R8E SEC21	C140	11.60	12.46	0.86

Table 13 - (continued)

Township Range & Section	Seep Stage	Shonkin Quadrangle duplicate map 1	map 2	Difference in mapped area
		----------acres----------		
T22N R8E SEC21	C550	unm[1]	0.93	0.93
T22N R8E SEC22	1	11.33	5.40	5.93
T22N R8E SEC22	2	7.65	7.23	0.42
T22N R8E SEC22	3	0.30	13.84	13.54
T22N R8E SEC22	C550	2.41	9.51	7.10
T22N R8E SEC23	1	7.22	7.98	0.76
T22N R8E SEC23	2	9.84	12.57	2.73
T22N R8E SEC23	3	0.52	unm[1]	0.52
T22N R8E SEC23	C550	0.99	1.09	0.10
T22N R8E SEC23	C221	24.92	26.95	2.03
T22N R8E SEC23	C150	3.26	3.58	0.32
T22N R8E SEC23	SD	3.94	unm[1]	3.94
T22N R8E SEC24	1	2.90	2.89	0.01
T22N R8E SEC24	2	17.22	37.61	20.39
T22N R8E SEC24	3	0.39	0.19	0.20
T22N R8E SEC24	C230	4.36	4.95	0.59
T22N R8E SEC24	SD	11.05	10.79	0.26
T22N R8E SEC25	2	9.11	4.00	5.11
T22N R8E SEC25	3	0.48	unm[1]	0.48
T22N R8E SEC26	2	2.09	2.02	0.07
T22N R8E SEC26	C450	3.10	3.21	0.11
T22N R8E SEC27	1	unm[1]	0.53	0.53
T22N R8E SEC27	2	52.87	40.46	12.41

Table 13 - (continued)

Township Range & Section	Seep Stage	Shonkin Quadrangle duplicate map 1	map 2	Difference in mapped area
		acres		
T22N R8E SEC27	3	7.54	5.90	1.64
T22N R8E SEC27	C450	5.24	5.10	0.14
T22N R8E SEC27	C340	1.26	1.43	0.17
T22N R8E SEC27	C540	2.21	2.05	0.16
T22N R8E SEC27	C350	12.41	11.92	0.49
T22N R8E SEC27	C320	11.11	10.36	0.75
T22N R8E SEC27	C550	9.92	unm[1]	9.92
T22N R8E SEC27	SD	19.73	20.79	1.06
T22N R8E SEC28	1	24.74	25.22	0.48
T22N R8E SEC28	2	28.82	27.48	1.34
T22N R8E SEC28	3	6.99	4.14	2.85
T22N R8E SEC28	C550	29.51	28.48	1.03
T22N R8E SEC28	SD	45.91	31.79	14.12
T22N R8E SEC29	1	unm[1]	2.44	2.44
T22N R8E SEC29	2	38.48	33.29	5.19
T22N R8E SEC29	3	3.29	0.99	2.30
T22N R8E SEC29	SD	64.19	67.37	3.18
T23N R8E SEC34	1	8.58	8.95	0.37
T23N R8E SEC34	3	4.73	4.58	0.15
T23N R8E SEC34	C230	34.47	36.16	1.69
T23N R8E SEC35	1	12.59	11.87	0.72
T23N R8E SEC35	2	3.59	3.82	0.23

Table 13 - (continued)

Township Range & Section	Seep Type	Shonkin Quadrangle duplicate map 1	map 2	Difference in mapped area
		----------acres----------		
T23N R8E SEC35	3	0.12	0.15	0.03
T23N R8E SEC35	SD	2.10	1.64	0.46
T23N R8E SEC36	1	1.36	1.52	0.16
T23N R8E SEC36	2	2.83	1.08	1.75
T23N R8E SEC36	3	unm[1]	1.33	1.33
T23N R8E SEC36	SD	1.34	3.43	2.09
Total Area		1241.82	1274.34	
Mean Area Per Seep		13.65	14.32	3.33
Standard Deviation		17.37	18.12	8.34
			Variance	3.64

1 - unm = Nothing mapped in a location where a saline seep was mapped previously or subsequently.

APPENDIX E

Repeatability of Measurement

TABLE 14. Repeatability of measurement of area using the Linear Measuring Set on 47 seeps.

TOWNSHIP & RANGE	SEC.	SEEP STAGE	MEASUREMENT NUMBER #1	#2	#3	#4	#5	#6 acres	MIN. VALUE	MAX. VALUE	MEAN VALUE	STD. DEV	%STD. DEV
T22N R8E	9 E1/2	1	13.4	13.1	13.2	13.4	13.0	13.3	13.0	13.4	13.2	0.1	1.13%
		2	19.1	19.1	18.8	19.2	18.8	19.1	18.8	19.2	19.0	0.2	0.91%
		3	1.2	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.2	0.0	0.76%
T23N R8E	28 S1/2	1	30.9	30.7	30.9	31.9	30.8	31.3	30.7	31.9	31.1	0.4	1.32%
		2	19.3	18.8	19.3	19.3	18.8	19.1	18.8	19.3	19.1	0.2	1.25%
		3	5.7	5.6	5.4	5.7	5.7	5.7	5.4	5.7	5.6	0.1	1.90%
T23N R8E	26 SE1/4	1	16.2	16.1	16.0	16.9	16.3	16.4	16.0	16.9	16.3	0.3	1.73%
		2	9.4	9.9	9.1	9.9	9.6	9.5	9.1	9.9	9.6	0.3	2.94%
		3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.0	4.79%
T22N R9E	6&7 W1/2	1	12.6	12.6	9.6	13.1	12.6	12.7	9.6	13.1	12.2	1.2	9.46%
		2	24.9	24.9	24.9	25.6	25.1	25.5	24.9	25.6	25.1	0.3	1.22%
		3	12.9	13.1	15.8	13.4	12.9	13.3	12.9	15.8	13.6	1.0	7.45%
T22N R7E	4 N1/2	1	15.0	15.3	15.2	15.5	15.0	15.4	15.0	15.5	15.2	0.2	1.24%
		2	16.4	16.7	16.4	16.8	16.4	16.6	16.4	16.8	16.5	0.2	1.02%
		3	1.1	1.1	1.2	1.1	1.1	1.0	1.0	1.2	1.1	0.1	6.06%
		2A	22.4	22.7	22.3	23.1	22.2	22.9	22.2	23.1	22.6	0.3	1.38%
T22N R7E	12 E1/2	1	4.1	4.0	3.9	4.1	4.0	4.0	3.9	4.1	4.0	0.1	1.37%
		2A	1.3	1.3	1.2	1.3	1.3	1.2	1.2	1.3	1.3	0.0	2.41%
		2B	2.3	2.3	2.2	2.3	2.3	2.3	2.2	2.3	2.3	0.0	1.28%
		2C	3.2	3.1	3.1	3.2	3.1	3.1	3.1	3.2	3.1	0.0	1.19%
		3C	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	7.09%
		3D	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.0	2.19%
		3E	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.0	1.87%
		3F	1.1	1.1	1.1	1.2	1.1	1.2	1.1	1.2	1.1	0.0	2.32%
		3G	0.7	0.6	0.6	0.7	0.6	0.7	0.6	0.7	0.6	0.0	3.38%
		3H	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.0	4.31%
		3I	1.7	1.7	1.7	1.8	1.8	1.8	1.7	1.8	1.8	0.0	1.70%
T22N R7E	12&13 SW	1	21.8	21.8	21.8	22.8	22.0	22.0	21.8	22.8	22.0	0.3	1.58%
		2A	2.4	2.4	2.4	2.5	2.4	2.4	2.4	2.5	2.4	0.0	1.61%
		2B	3.3	3.3	3.3	3.5	3.3	3.3	3.3	3.5	3.4	0.1	1.53%
T22N R7E	24 N1/2	2A	19.0	19.1	19.2	20.3	19.6	19.3	19.0	20.3	19.4	0.5	2.35%
		2B	3.9	3.8	3.8	3.9	3.9	3.9	3.8	3.9	3.8	0.0	1.23%
		2C	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.0	3.20%
		2D	1.5	1.5	1.5	1.5	1.5	1.6	1.5	1.6	1.5	0.0	1.24%
		2E	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.5	0.4	0.0	5.00%
		2F	4.4	4.4	4.3	4.5	4.5	4.5	4.3	4.5	4.4	0.1	1.35%
		2G	2.2	2.2	2.2	2.3	2.2	2.3	2.2	2.3	2.2	0.0	1.00%

TABLE 14 (continued)

TOWNSHIP & RANGE	SEC.	SEEP STAGE	MEASUREMENT NUMBER (ACRES) #1	#2	#3	#4	#5	#6	MIN. VALUE	MAX. VALUE	MEAN VALUE	STD. DEV	%STD. DEV
			acres										
		2H	0.6	0.7	0.6	0.7	0.6	0.7	0.6	0.7	0.6	0.0	3.06%
		3	8.3	8.4	8.4	8.9	8.6	8.6	8.3	8.9	8.5	0.2	2.41%
		C510	65.5	63.9	64.8	67.8	66.4	66.4	63.9	67.8	65.8	1.2	1.89%
T22N R7E	24	2A	0.7	0.7	0.6	0.7	0.7	0.7	0.6	0.7	0.7	0.0	2.93%
		2B	54.0	54.1	53.1	53.5	54.6	55.0	53.1	55.0	54.0	0.6	1.15%
		3A	1.6	1.5	1.5	1.6	1.6	1.6	1.5	1.6	1.5	0.0	1.28%
		3B	0.9	1.0	0.9	0.9	0.9	1.0	0.9	1.0	0.9	0.0	2.88%
		3C	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.8	0.7	0.0	2.76%
T22N R7E	11 SW1/4	1	9.2	9.5	9.1	9.6	9.2	9.5	9.1	9.6	9.3	0.2	2.04%
		2	26.7	26.0	26.4	27.7	27.0	26.7	26.0	27.7	26.8	0.5	2.00%
		3	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.0	2.68%
TOTAL (acres)			451.9	463.7	461.8	477.9	467.2	471.1					

AVG. STD	2.49%
MAX. STD	9.46%
MIN. STD	0.76%
STD. DEV	1.82%
AVG.	465.6
STD DEV	8.1
MAX	477.9
MIN	451.9
%STD DEV	1.73%

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