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A RISK-BASED RANKING SYSTEM FOR CDOT SALT PILE FACILITIES

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16. Abstract

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The goal of this research is to produce a preliminary facility ranking system, utilizing a risk-based model, that is protective of human health and the environment for salt contamination in soil, groundwater and surface water. Concurrent and parallel activities are to identify salt toxicity values that are appropriate to the ecosystem and habitat in which a facility is located and to develop an approach to identify and evaluate potential impacts to groundwater that may be used as a drinking water source. The objective is to replace a highly subjective background-based standard for remediation with a risk-based, toxicological approach that is based on sound science and meets statutory requirements.

The current background approach to remediation of salt-contaminated soil is very expensive and is not linked to site-specific protection of human health and the environment. A site-specific, risk-based facility ranking system will provide CDOT with a strategy for allocating limited resources and will be the basis of a planning process for the cleanup of facilities in a prioritized, protective and cost-effective manner. CDOT will be able to use a broad-based and consistent, risk-based model, customized by physiographic region and county for key site parameters, as a screening tool to:

- Rank the priority of a site for further investigation;
- Conduct a preliminary site-specific, risk-based screen at high priority sites; and
- Evaluate the potential extent of contamination for mitigation or remediation purposes.

It is anticipated that this risk-based approach will cut remediation costs substantially. Currently, regulations require that background be assessed and salt levels compared to background without the benefit of looking at the potential risk to receptors. This process will allow the vulnerability of the media that transport the salt, and the vulnerability of the receptors to that salt will determine cleanup actions. The estimation is that tens of millions of dollars in cleanup monies will be saved by the taxpayers.

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EXECUTIVE SUMMARY

Many of the Colorado Department of Transportation's (CDOT) 200 maintenance yards are contaminated with sodium chloride (NaCl) after decades of using sand/salt piles that were stored in the yard and exposed to the elements. The current regulatory approach stipulated by the Colorado Department of Public Health and Environment (CDPHE) is to determine a background level of salt in the immediate area and require CDOT to remediate the contaminated soil down to a level that is no more than three times background concentrations. CDOT recently spent $158,000 excavating the on-site "contaminated" portion of the maintenance yard at Soda Lakes (on Hampden in Lakewood) and still needs to address the off-site impacts. The estimated cost to remediate up to 200 maintenance yards ranges from $10 million to $40 million.

The goal of this research is to produce a preliminary facility ranking system, utilizing a risk-based model, that is protective of human health and the environment for salt contamination in soil, groundwater and surface water. Concurrent and parallel activities are to identify salt toxicity values that are appropriate to the ecosystem and habitat in which a facility is located and to develop an approach to identify and evaluate potential impacts to groundwater that may be used as a drinking water source. The objective is to replace a highly subjective background-based standard for remediation with a risk-based, toxicological approach that is based on sound science and meets statutory requirements.

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Rank the priority of a site for further investigation,

- Conduct a preliminary site-specific, risk-based screen at high priority sites, and

- Evaluate the potential extent of contamination for mitigation or remediation purposes.

It is anticipated that this risk-based approach will cut remediation costs substantially. Currently regulations require that background be assessed and salt levels compared to background without the benefit of looking at the potential risk to receptors. This process will allow the vulnerability of the media that transport the salt and the vulnerability of the receptors to that salt determine cleanup actions. The estimation is that tens of millions of dollars in cleanup monies will be saved by the taxpayers.

Implementation Statement

It is recommended that CDOT install the software tool at the CDOT Property Management office in Denver. The tool requires some site-specific information to be acquired by CDOT personnel from the Property Management office through a site visit and consultation with the facility manager. Appendix C of this report includes an electronic copy of the Ranking Tool and a User Guide with installation instructions.

The following procedure should be followed:

1) Install software tool at each designated computer in the CDOT Property Management office in Denver.
2) Review the Step One ranking results for any or all salt pile facilities
3) For facilities deemed by CDOT to have a high ranking from Step One, go to Step Two.
4) Step Two requires a site visit by an environmental technician and consultation with the facility manager.
5) For facilities deemed by CDOT to have a high ranking from Step Two, go to Step Three.
6) Step Three is a Site Investigation. Detailed Site Investigation procedures are out of the scope of this project.

The benefit of this program is that salt pile facilities with the highest vulnerability to contamination from salt will be identified and investigated first. The environmental benefits of this research are protection of human, ecological and agricultural downgradient receptors of groundwater, surface water, soil, vegetation and biota.

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1.0 INTRODUCTION

Many of Colorado Department of Transportation's (CDOT) 200 maintenance yards are contaminated with sodium chloride (NaCl) after decades of using sand/salt piles that were stored in the yard and exposed to the elements. More recent leaks and spills from magnesium chloride ($MgCl_2$) salt tanks stored above ground also may have contaminated the local soil. The current regulatory approach stipulated by Colorado Department of Health and Environment (CDPHE) is to determine a background level of salts in the immediate area and require CDOT to remediate the contaminated soil down to a level that is no more than three times background concentrations. CDOT recently spent $158,000 excavating the on-site "contaminated" portion of the maintenance yard at Soda Lakes (on Hampden in Lakewood) and still needs to address the off-site impacts. The estimated cost to remediate up to 200 maintenance yards ranges from $10 million to $40 million.

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- Evaluate the potential extent of contamination for mitigation or remediation purposes.

It is anticipated that this risk-based approach will cut remediation costs substantially.

Waterstone Environmental Hydrology and Engineering, Inc. (Waterstone) was retained by CDOT to:

- Review programs in other states that address environmental contamination from salt pile facilities,
- Develop a preliminary facility ranking system, utilizing a risk-based model, that is protective of human health and the environment for salt contamination in soil, groundwater and surface water,
- Identify toxicity values appropriate for the variety of ecosystems and potential downgradient human and ecological receptors, and
- Develop an approach to identify and evaluate potential impacts to groundwater that may be used as a drinking water source.

The remainder of this report is organized as follows:

- Section 2 Review of Programs in Other States
- Section 3 Salt Pile Facility Ranking System
- Section 4 Toxicity Values for Use in Site-Specific Investigations
- Section 5 Pilot Test of Ranking System
- Section 6 Ranking Tool and User Guide
- Section 7 Conclusions and Recommendations

2.0 REVIEW OF PROGRAMS IN OTHER STATES

The first step in creating the maintenance facility ranking system was a review of programs in other states to address environmental concerns caused by salt piles. Information from state Department of Transportations (DOT) was collected. The most relevant information is described below.

The review of programs in other states included an extensive internet search and direct contact with selected state DOTs. The internet search included state DOT web sites, U.S. Environmental Protection Agency (EPA) regional web sites, and/or state Department of Environmental Quality (DEQ) web sites. The information gathered through this effort was limited and it was not always possible to determine what experience the given state(s) had with implementing their program. To supplement this information, Waterstone telephoned all state DOTs with winter road snow and ice control programs. The telephone survey collected information on many aspects of each state's experience with storage, handling, and evaluating impacts of road salts.

Waterstone identified only two states, Maine and Michigan, with active environmental risk-based programs to rank salt storage facilities. Both states have developed risk-based programs that rely on a scoring system to prioritize the risk posed by each salt storage facility. Each state program is quite different and neither program is as comprehensive as the program that Waterstone has developed for CDOT. Waterstone also located information regarding Canada's response to environmental impacts from road salt, as described below.

2.1 Maine's Sand and Salt Storage Program

The state of Maine first recognized the impact of road salts to the environment in 1984 when the Maine Department of Environmental Protection (MDEP) issued a report describing ground water contamination at salt storage facilities. The MDEP report recommended that an assessment of all public and private sand/salt storage facilities be undertaken for the entire state. In 1985 the Maine State Legislature required that all public and private sand/salt storage facilities be registered with the MDEP by the beginning of 1986. The Legislature also amended the MDEP statute to provide funding of up to 50% of the costs for building covered municipal sand/salt storage facilities. In 1986 MDEP personnel visited each of the 500 registered sites to prioritize their risk to ground water. Each site was placed in one of five categories based on the quantifiable impact of the facility on developed groundwater. Funding problems suspended the program and no additional work was completed until 1998 when the Sand and Salt Pile Task Force (the Task Force) was convened by the Maine DOT and the MDEP. The first step taken by the Task Force was to re-register all of the state's public and private sand/salt storage facilities. A registration form was mailed to all municipalities and the responses were used to take a "first cut" to determine which facilities required an on-site MDEP or DOT assessment. The key questions on the registration form were whether there was any visible damage to vegetation, the distance to the nearest drinking water well and the facilities location relevant to the 1986 registration survey. Each of the on-site assessments considered the following five criteria for prioritizing the facilities (*Sand and Salt Storage in Maine*, Report to the 120th Maine Legislature, January 26, 2001):

1) Ground water monitoring data from nearby wells, or, if there are no wells to sample, the presence or absence of a public water system. The starting point of the priority setting process mirrored the 1986 system so as to provide initial consistency between project lists. The ranking system was still weighted heavily to the protection of local drinking water.

2) The extent of visible damage to trees and wetlands. Because of the effort and resources that would be needed to quantify such damage, a qualitative assessment was done. The impact was judged by investigating staff as *none* (no noticeable or substantive damage to grass and low-growing vegetation), *slight* (dead grass/vegetation, browning of leaves and needles/desiccation effects on trees), *moderate* (dead trees and a larger area of dead grass/vegetation), *severe* (multiple trees and vegetation species dead, significant area where vegetation is incapable of growing).

3) Whether the pile is located in an area zoned for commercial, industrial or similar use, or, in the absence of zoning, the likelihood that new houses with wells would be built near the sand/salt pile. Zoning was factored in because municipalities have it within their powers to place sand/salt piles -- public and private -- in areas unlikely to experience residential development and thus reduce the likelihood of impacts to future drinking water supplies.

4) Distance to the nearest public water supply well and intake. To complement on-going source water protection efforts, a sand/salt pile's risk was considered higher if it was located within 2500 feet of a public water supply well or intake. Geospatial data on the location of public wells and intakes was provided by the Department of Human Services, Drinking Water Program.

5) Whether the sand/salt pile is located on a significant sand and gravel aquifer. Significant sand and gravel aquifers are considered a unique ground water resource and are mapped by the Department of Conservation, Maine Geological Survey (MGS). MGS provided current geospatial data to DEP for this determination.

All of the sites that made it through the "first cut" were evaluated by the Maine DOT and MDEP personnel using the five criteria detailed above. Each registered site was given a ranking number from 1 to 5 with 1 indicating a very high priority and five indicating low risk. Waterstone was not able to determine the precise methods that were used to derive the ranking number of each site from the above criteria. It is assumed that the assignment of priority numbers was based primarily upon a qualitative assessment of the site performed by the inspecting personnel. The Maine program did not have a significant component designed to quantify ecological risk. The ecological component focused only on existing damage to vegetation in the immediate surroundings of sand/salt storage facilities. The program did not address potential impacts to nearby surface water bodies, though a limited number of surface water samples were analyzed for chlorides. The primary corrective action recommended by the Maine program is sand/salt storage facility building construction or other waterproof coverings.

2.2 Michigan's Hazardous Substances Site Scoring Program

Michigan has developed a comprehensive risk-based assessment model that utilizes a scoring system for hazardous substances site prioritization. Michigan's model is applied to any and all sites at risk for releases of any hazardous substances, including road salts. At the heart of Michigan's model is a six category scoring system. The sum of the points derived from each category directly determines the overall score for a site; the higher the score, the greater the risk to human health and the environment. The six categories used in the Michigan model are:

1) Environmental Contamination. Points are applied for each impacted media (soil, groundwater, surface water, and air). Point values are dependent on whether contamination of each media is potential, suspected, confirmed, or has impacted human health.

2) Mobility Ratings. Points are applied based upon the expected mobility of the material. Mobility is determined primarily by the physical nature of the substance (i.e. solid, liquid, or gas).

3) Sensitive Environmental Resources. Points are applied if: 1) a "natural community" within ½-mile of the site has been classified by the Department of Natural Resources as uncommon, rare, or extremely rare, or 2) a plant or animal that has been classified as of special concern, threatened, or endangered is located within ½-mile of the site. Points increase for each occurrence of either condition within ½-mile of the site. No points are given if only groundwater has been impacted and if sensitive environmental resources are not directly threatened or potentially affected by corrective actions at the site.

4) Population. Points are applied for population density within ½-mile of the site, or the density of the population potentially exposed through an exposure pathway that extends outside the target area, whichever is greater. Population density is measured in persons per square mile and logarithmic divisions in population density determine point values.

5) Institutional Population. One point is applied when at least one occupied school, hospital, licensed childcare center, or nursing home is within ½-mile of the site.

6) Chemical Hazard. Points are applied by one of two methods: 1) for known substances and concentrations, points are applied based on the ratio of chemical concentrations to cleanup criteria, or 2) for unidentified substances, points are applied based on the approximate quantity of the substance(s) and their "Waste Class", which is dependant upon the waste source or business type which was responsible for the generation of the substance(s). Salt Storage is one of the listed business types, but it is in the lowest waste class. Severely toxic wastes are automatically given the highest possible Waste Class score.

Michigan's model is not specific to salt contamination and does not address some of the specific concerns regarding the impact of salt storage facilities to the environment. Specifically, no provision is made for degradation to ecological communities that are not already endangered; there is no consideration of the proximity of a release site to either groundwater resources or surface water; and the mobility rating category does not include a category for highly soluble solids that can become very mobile once in solution.

2.3 Other State's Responses to Road Salt Environmental Concerns

Waterstone contacted Department of Transportation personnel from 37 states within the United States to gather information that was found to be lacking in the web based research originally conducted. Responses were received from 22 of the 37 states and all available information regarding the individual state's experience with road salt impact to the environment was collected. None of the states (excluding Maine and Michigan) have begun to develop programs for addressing the environmental impacts of salt storage facilities. Most states have at least begun to build covered facilities for salt storage although only four of the states have actually developed written directives or best management plans (BMPs) governing the storage of salts. Only three states were confirmed to be currently using cyanide based compounds to retard clumping of their salt piles, none of these states have encountered problems regarding the use or release of cyanide to the environment. None of the states have developed statewide toxicity limits for chlorides in the environment, those states who have encountered chloride problems use the EPA's Secondary Maximum Contaminant Limit of 250 parts per million (ppm, mg/L) in water. There is a single site in Idaho where a salt storage facility was found to have contributed significant chloride releases to soil and groundwater and the environmental consultant for the project has recommended a cleanup goal of 50 ppm for soil.

2.4 Canada's Experience with Road Salt Environmental Concerns

Canada has determined that road salts are a toxic substance as defined in the *Canadian Environmental Protection Act, 1999* (CEPA, 1999). An effort has been made throughout Canada to limit the use of salts in the winter maintenance of roads and to cover and contain all salt storage facilities and snow storage/disposal locations. Waterstone located a document produced by the Government of Alberta Environmental Department titled *Generic and Risk-Based Approaches for Salt Contaminated Sites*. The document summarizes the necessary elements of a balanced risk-based program for assessing salt-contaminated sites. The document suggests that risk assessment is appropriate when "generic guidelines [for soil and groundwater concentrations] do not account for site-specific exposure conditions [, or] significant or sensitive receptors [may be affected]". The elements of the risk assessment should be receptors (humans, animals, plants, insects, and ecosystem), exposure (concentration and pathways), and hazards. Consideration of these elements should address present conditions and future impacts, including potential new receptors and exposure pathways and contaminant transport. Current land use zoning will determine potential receptors and exposure pathways and unconditional site "closure" should not restrict future activities that are allowed by the current zoning. The Alberta regulatory approach recommends the use of computer modeling to determine the potential for contaminant transport. Alberta's approach does not specify a ranking or scoring process to determine the relative severity of salt storage facilities impacts to the environment.

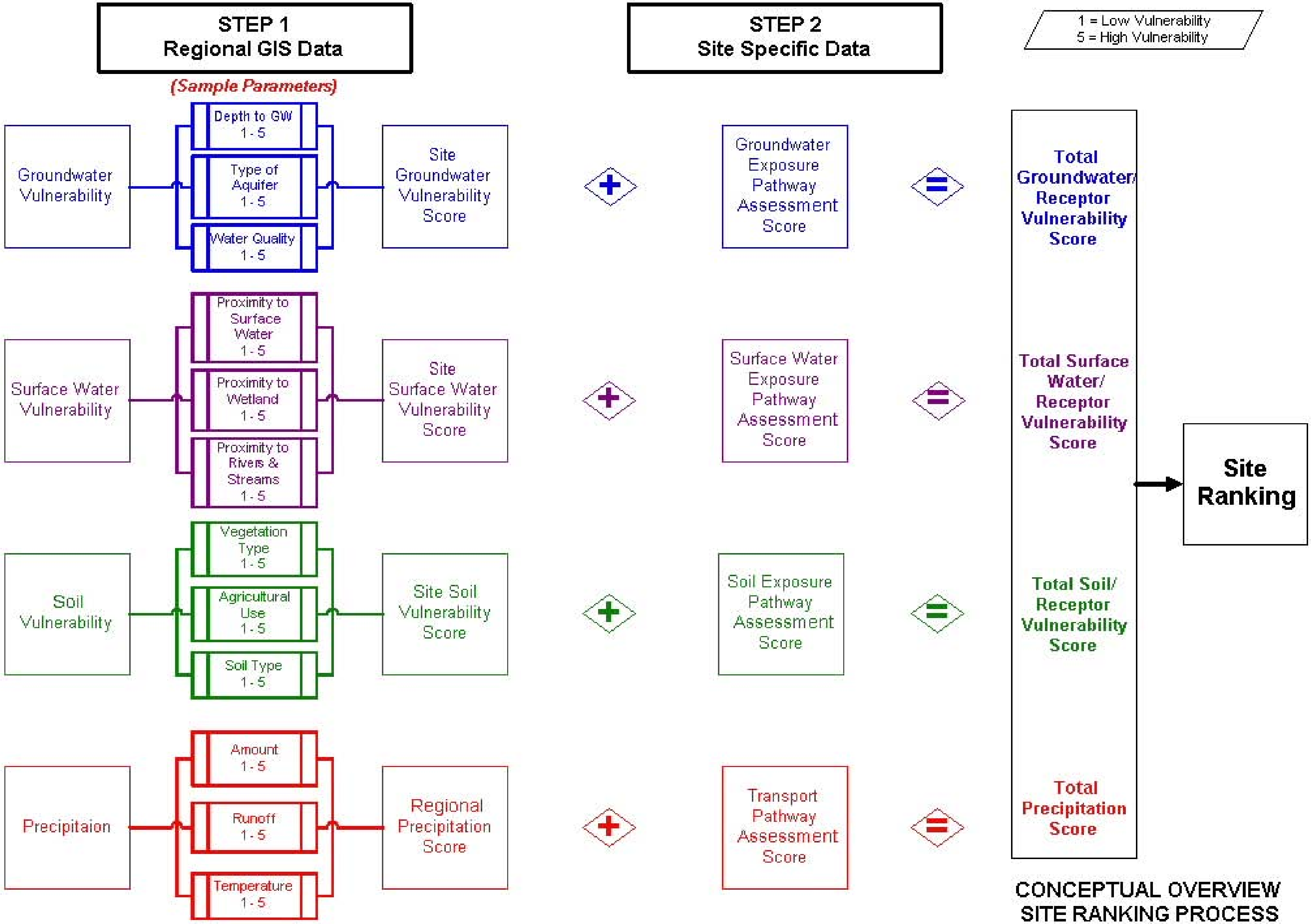
3.0 SALT-PILE FACILITY RANKING SYSTEM

As mentioned previously, one goal of this research is to produce a preliminary salt pile facility ranking system, utilizing a risk-based model, that is protective of human health and the environment for salt contamination in soil, groundwater and surface water. This section describes the two-step process of the facility ranking system. Both steps are risk-based in the sense that they consider the likelihood of salt transport in local media (Step One) and the sensitivity of local receptors to environmental salts (Step Two). Step One is a desk-top, pre-programmed ranking that focuses on the vulnerability of local soil, surface water and groundwater to impacts from salt storage facilities, described in Section 3.1. Step Two is a ranking based on observations during a site visit that focuses on the vulnerability and sensitivity of local human and ecological receptors to impacts from salt storage facilities, described in Section 3.2. Figure 3-1 provides a conceptual overview of Steps One and Two.

3.1 Step One: Pre-Programmed Media Vulnerability Ranking

3.1.1 Methods Colorado is composed of a variety of diverse physiographic environments including the eastern plains, front range, rocky mountains, northwestern slope and southwestern slope. Table 3-1 summarizes four of the major features in each type of environment. Soil, surface water and groundwater in these diverse environments may facilitate or impede migration of salt from salt piles to adjacent downgradient locations. Waterstone assembled state-wide information on geology, topography, soil types, climate, water bodies, physiographic regions, and vegetation types to develop Geographical Information System (GIS) coverages that could be mapped relative to specific facility locations.

This mapping effort allows facility-specific information to be identified “automatically” via GIS functions. This information can then be evaluated to develop a “rank” for each facility. Table 3-2 lists the questions that are answered in Step One via the GIS and illustrates how specific answers are scored. The following paragraphs describe the assumptions underlying the scoring system for each media and for climate information.



CONCEPTUAL OVERVIEW
SITE RANKING PROCESS
FIGURE 3-1

TABLE 3-1
SUMMARY OF MAJOR REGIONAL ENVIRONMENTAL FEATURES

	Region 1 - Eastern Plains	Region 2 - Alpine/Montane	Region 3 - Northwest Slope	Region 4 - Southwest Slope	Region 5 - San Luis Valley
Precipitation	Less than 20 inches per year throughout the region.	13 to 63 inches per year.	Generaly less than 20 inches per year.	Generally less than 20 inches per year.	Less than 9 inches per year throughout the region.
Major Vegetation Type	Primarily grassland significant agricultural use.	Primarily conifers and high altitude deciduous trees, some isolated valleys with grassland and shrubland, limited agricultural use.	Mostly grasslands with some shrubland and chaparral, some agricultural use.	Mostly shrub land and chaparral with some agricultural use and occasional grasslands.	Primarily grasslands with a large component of agricultural use.
Geologic Features	Primarily un-lithified alluvial material.	Steeply sloping mountainsides dominated by hardrock outcrops, alluvial material in valleys.	Mostly un-lithified alluvium with areas of bedrock outcropps.	Mostly un-lithified alluvium with a significant component of bedrock outcrops.	Moslty un-lithified alluvial material.
Soil Permeability	~70% of Soils have permeability rates below 2 inches per hour.	~60% of soils in the region have permeability rates of less than 2 inches per hour.	~ 65% of the soils in the region have permeabilty rates in excess of 2 inches per hour.	~95% soils with permeability rates of less than 2 inches per hour.	~90% of soils have permeability rates in excess of 2 inches per hour.

TABLE 3-2
CDOT SALT PILES RESEARCH PROJECT
SITE RANKING PROCESS

STEP 1 QUESTIONS[1]

Environmental Factor	Media Vulnerability Score Low 1	2	3	4	High 5
Groundwater					
▪ Aquifer type	Igneous/Metamorphic	Shale/Limestone	Shale	Sand/Shale	Sand/Gravel
▪ Depth to groundwater (feet)	>40	>30≤40	>20≤30	>10≤20	≤10
▪ Soil permeability (inches per hour)	≤0.2	>0.2≤0.6	>0.6≤2	>2≤6	>6≤20
Surface Water					
▪ Proximity to lake or pond (miles)	>5	>3≤5	>1≤3	>0.5≤1	≤0.5
▪ Proximity to river or stream (miles)	>5	>3≤5	>1≤3	>0.5≤1	≤0.5
▪ Proximity to wetland (miles)	>5	>3≤5	>1≤3	>0.5≤1	≤0.5
▪ Soil permeability (inches per hour)	>6≤20	>2≤6	>0.6≤2	>0.2≤0.6	≤0.2
Soil					
▪ Soil classification	Clay	Silt	Organic	Sand	Gravel
▪ Vegetation type	Alkali grassland	Pasture/grassland	Pinyon/juniper	Riparian/Crops	Pine/fir
▪ Proximity to agricultural use (miles)	>5	>3≤5	>1≤3	>0.5≤1	≤0.5
Climate					
▪ Precipitation (average inches/year)	≤10	>10≤15	>15≤25	>25≤40	>40
▪ Average temperature range (^{0}F)	>50	>45≤50	>40≤45	>35≤40	≤35
▪ Average snowfall (inches)	>150	>100≤150	>60≤100	>30≤60	≤30

[1]These questions are answered via the ranking tool and are based on GIS coverages.

Groundwater Assumptions

- *Aquifer Type* – The more permeable the aquifer matrix, the greater the potential for migration of salt into groundwater
- *Depth to groundwater* – The shallower the groundwater table, the more likely the salt will enter the aquifer and flow offsite
- *Soil permeability* - The higher the soil permeability, the greater the chance for migration of salt into the groundwater

Surface Water Assumptions

- *Proximity to lake/pond* – The closer a lake or pond is to a salt pile the more likely salt runoff will affect the surface water quality and potential receptors
- *Proximity to river/stream* - The closer a river or stream is to a salt pile, the more likely salt runoff will affect the surface water quality and potential receptors
- *Proximity to wetland* - The closer a wetland is to a salt pile, the more likely salt runoff will affect wetland quality and potential receptors
- *Soil permeability* – The lower the soil permeability, the greater the likelihood of ponding and runoff into surface water bodies

Soil Assumptions

- *Soil Type* – Clays can retain water and act as a barrier or absorption mechanism to the movement of salt, more so then gravels, thereby restricting the offsite migration of the salt.
- *Vegetation Type* – Significant variation exists in the salt tolerance of various types of vegetation. For example, pines and firs are much more sensitive to salt than alkali grasslands.
- *Proximity to agricultural land* – Salt can create a soil environment unsuitable for agricultural purposes.

Climate Assumptions

- *Precipitation Amount* – The greater the precipitation, the more likely there will be runoff and/or infiltration resulting in offsite migration of salt

- *Temperature* – The higher the average temperature, the less snow and the more evapotranspiration, resulting in less runoff and less infiltration
- *Snowfall* – The higher the average snowfall, the more salt will be used for snow on the roads, the more salt transport activity per site and the more likely there will be runoff and infiltration resulting in offsite migration of salt.

3.1.2 Results

To summarize the results of Step One for all 178 maintenance facilities with salt pile storage, a preliminary prioritization scoring was developed. Overall scores for Step One ranged from a low of 38 to a high of 75. A facility score of 0-51 was considered a low priority facility. A score of 52-62 was considered medium priority and a score of 63-100 was considered a high priority facility. Table 3-3 summarizes the results of this scoring for the 178 facilities.

Table 3-3. Results of Step One for All Facilities

Score	Priority	Number of Facilities	Percent of Total
0-51	Low	44	25%
52-62	Medium	102	57%
63-100	High	32	18%
	Total	178	100%

3.2 Step Two: Site Observation-Based Receptor Vulnerability Ranking

Step Two incorporates site-specific data, knowledge and observations into the ranking system. Step Two questions, listed in Table 3-4, estimate the likelihood that exposure pathways are complete and the vulnerability of potential human or ecological receptors.

Table 3-4 lists the questions that are answered in Step Two during a site visit and how specific answers are scored. The following paragraphs describe the assumptions underlying the scoring system for each media.

TABLE 3-4
CDOT SALT PILES RESEARCH PROJECT
SITE RANKING PROCESS

STEP 2 QUESTIONS[1]

Environmental Factor	Low	Receptor Vulnerability Score			High
	1	**2**	**3**	**4**	**5**
Groundwater					
▪ Distance to nearest downgradient gw well used for human consumption (feet)	>1,000	>600≤1,000	>400≤600	>200≤400	≤200
▪ Proximity to downgradient gw well for livestock (feet)	>1,000	>600≤1,000	>400≤600	>200≤400	≤200
▪ Proximity to downgradient gw well for agriculture (feet)	>1,000	>600≤1,000	>400≤600	>200≤400	≤200
▪ Average depth to gw onsite of facility (feet)	>40	>30≤40	>20≤30	>10≤20	≤10
▪ Average depth to gw offsite w/in 1500 ft downgradient of facility (feet)	>40	>30≤40	>20≤30	>10≤20	≤10
▪ Water quality in nearest downgradient or onsite well (TDS) (mg/L)	≤250	>250≤500	>500≤1,000	>1,000≤3,000	>3,000
▪ Water quality in nearest upgradient well (TDS) (mg/L)	>3,000	>1,000≤3,000	>500≤1,000	>250≤500	≤250
Surface Water					
▪ Proximity to downgradient lake or pond (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Proximity to downgradient river or stream (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Proximity to downgradient wetland (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Water conductivity in nearest downgradient surface water body within ¼ mile (dS/cm)	None	≤4	>4≤7	>7≤10	>10
▪ Water conductivity in nearest upgradient surface water body within ¼ mile (dS/cm)	>10	>7≤10	>4≤7	≤4	none
▪ Slope of ground from site to lowest point downgradient within ¼ mile	≤3	>3≤6	>6≤10	>10≤15	>15

(degrees)					
▪ Evidence of erosion to any surface water body	None	Some	Moderate	Significant	Severe
▪ Aquatic organisms in nearest downgradient surface water body	None	Warm water species	Mixed	Limited cold water species	Cold water species
▪ Proximity to downgradient surface water feature used for agricultural irrigation or livestock watering (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Agricultural irrigation use of nearest downgradient surface water w/in ¼ mile	None	Pasture	Grains	Horticulture	Vegetables and fruit
▪ Livestock use of nearest downgradient surface water w/in ¼ mile	None	Minimal livestock use	Sheep, horses, and beef cattle	Dairy cattle and swine	Chickens and turkeys
Soil					
▪ Evidence of soil staining off-site	None	Some	Moderate	Significant	Severe
▪ Vegetation type w/in ¼ mile surrounding the site	Alkali grassland	Pasture/ Grassland	Pinyon/ Juniper	Riparian/ Crops	Pine/ Fir
▪ Evidence of vegetation impacts	None	Some	Moderate	Significant	Severe
▪ Proximity to downgradient agricultural use (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Proximity to downgradient livestock use (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Proximity to downgradient endangered plants (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Soil conductivity off-site and downgradient w/in 1500 ft (dS/m)	≤5	>5≤10	>10≤15	>15≤20	>20

[1] These questions are answered by CDOT staff, based on site knowledge and on-site observations.

3.2.1 *Groundwater Assumptions*

- *Distance to nearest downgradient domestic or livestock well* –The closer a downgradient well, the greater the likelihood of a complete exposure pathway
- *Depth to groundwater within ¼ mile* – the shallower the groundwater table, the more likely the salt will enter the aquifer and flow offsite (a more accurate depth estimate is assumed here than in Step One)
- *Total dissolved solids (TDS) in nearest up- and downgradient wells* – Indicates extent of potential impact, should downgradient exposure pathway be complete

3.2.2 *Surface Water Assumptions*

- *Proximity to surface water body or wetland* – The closer a downgradient water body or wetland, the greater the likelihood of a complete exposure pathway
- *Slope and evidence of erosion* – The greater the slope and/or evidence of erosion, the greater the likelihood that there will be a complete pathway to a surface water body
- *Aquatic organisms in nearest surface water body* – Aquatic organisms, like vegetation, vary significantly in their salt/TDS tolerance. Differences in sensitivity are accounted for in the scoring of this category.
- *Livestock use of surface water* –Livestock vary significantly in their salt/TDS tolerance. Differences in sensitivity are accounted for in the scoring of this category.

3.2.3 *Soil Assumptions*

- *Evidence of staining* – Indicates potential transport of salts offsite
- *Vegetation type in vicinity* – Estimate of sensitivity of potential plant receptors to increased soil conductivity
- *Evidence of impacts to vegetation* – Indication of past transport of salts and of sensitive vegetation
- *Proximity to agricultural land* – Type of agricultural use can be related to soil conductivity and salt tolerance
- *Soil conductivity* – Increases in soil conductivity can be related to transport of salts and to potentially sensitive plant receptors

- *Proximity to threatened or endangered plants* – Proximity to threatened or endangered plant species increases potential risk because these species need to be protected at an individual level.

4.0 TOXICITY VALUES FOR USE IN SITE-SPECIFIC INVESTIGATIONS

As discussed in Section 3, the entire ranking system is risk-based, focusing on the likelihood that salt may migrate to potential receptors and the vulnerability and sensitivity of those receptors. Sensitivity and toxicity information incorporated into Steps One and Two was derived from a document developed for the Colorado Department of Public Health and the Environment (CDPHE) entitled "CDOT Salt Piles Research Project – Toxicity Evaluation", included as Appendix B. This document was also used to establish toxicity-based, site-specific guidelines for salt-impacted soil, surface water and groundwater. These guidelines are to be applied when conducting site-specific media investigations to evaluate potential risk to human and ecological receptors. Variations in guidelines for ecological and agricultural receptors are based on the fact that plants, livestock and wildlife vary considerably in their tolerance of environmental salt. Therefore, guidelines for evaluating salt-impacted soil in an alkali grassland environment could and should be different than guidelines for evaluating salt-impacted soil in a riparian environment.

This section summarizes the results of the toxicity evaluation. Regional guidelines were developed for sodium chloride and TDS (conductivity) based on potential impacts to soil and subsequent impacts to groundwater and surface water via the soil pathway for vegetation and aquatic life. In addition, guidelines were also developed for the use of surface water or groundwater for irrigation and stock watering and for the use of groundwater as drinking water. These guidelines are intended for use in site-specific investigations conducted subsequent to Step Two of the facility ranking system.

Information considered in developing regional guidelines included current regulatory guidelines, available toxicological information, and regional ecosystem information. Toxicity information is segregated to reflect the major ecosystem species groups within the five regions of Colorado. For each major ecosystem group identified in Table 3-1, ranges of toxicity values are listed in Table 4-1. Table 4-2 identifies general regional values that would be considered in site-specific

TABLE 4-1
PHYSIOGRAPHIC REGION SALINITY TOLERANCE VALUES

Physiographic Region	Typical Plant Species	Threshold Soil Salinity Tolerance (dS/m)	Typical Aquatic Species	Threshold Aquatic Salinity Tolerance	
				NaCl (mg/L)	dS/m
1	Blue grama grass (alkali sacaton)	16 to 20	warm water species (fathead minnow)	4000-6000	5 to 8
1	Buffalo grass	8			
1	Pasture and forage crops	8 to 16			
2	Spruce Fir	2 to 4	aquatic insects	4 to 7	0.01
2	Douglas Fir	2 to 4	trout	1000-1500	1 to 2
2	Lodgepole Pine	2 to 4			
2	Aspen	2 to 4			
2	Willow	4			
3	Pinyon pine	8	warm water species (fathead minnow)	4000-6000	5 to 8
3	Juniper	8	aquatic insects	4 to 7	0.01
3	Grassland	4 to 8	trout	1000-1500	1 to 2
3	Fruit and vegetable crops	2 to 4			
3	Pasture and forage crops	8 to 16			
4	Pinyon pine	8	warm water species (fathead minnow)	4000-6000	5 to 8
4	Juniper	8			
4	Creosote	10			
4	Silver buffalo berry	16			
5	Alkali grassland	14-18	warm water species (fathead minnow)	4000-6000	5 to 8
5	Pasture and forage crops	8 to 16			

TABLE 4-2
PHYSIOGRAPHIC REGION SALINITY GUIDELINES

Physiographic Region	Proposed Regional Salinity Tolerance Guidelines		
	Soil	Aquatic	
	(dS/m)	(mg/L NaCl)	(dS/m)
1	8 to 16	4000-6000	5 to 8
2	2 to 4	4 to 7 (aquatic insects)	0.01
		1000-1500 (trout)	1 to 2
3	4 to 8	4 to 7 (aquatic insects)	0.01
		1000-1500 (trout)	1 to 2
4	8 to 10	4000-6000	5 to 8
5	10 to 15	4000-6000	5 to 8

investigations of vegetation and aquatic life. Clearly, specific local species of vegetation and aquatic life would need to be considered as part of any specific facility investigation. For example, the presence or absence of cultivated crops could make a significant difference on acceptable soil salinity values at a specific facility.

Table 4-3 illustrates current recommendations from the Food and Agriculture Organization of the United Nations for water quality for livestock and poultry (Ayers and Westcot 1994). In general, this table illustrates that avian species are more sensitive than mammals and that cattle and sheep can likely tolerate conductivity values up to at least 8000 mg/L of NaCl (approximately 10 dS/m) with little or no effect.

Potential Human Consumption of Salt-Contaminated Groundwater

The primary human health concern related to salt piles in the potential consumption of salt-contaminated groundwater. Studies on the toxicity of salt to humans have focused primarily on overall dietary salt intake. Estimates of typical daily salt intake for Americans range from 6000-9000 mg/day, with the primary source being processed foods (COMA 1994). Drinking water typically contributes very little to overall salt intake because municipal water treatment facilities remove most of the total dissolved solids (TDS). Taste thresholds and acceptability for sodium chloride concentrations in drinking water range up to 500 mg/L (Zoeteman, BCJ 1978). The USGS definition of freshwater is water with a TDS concentration $\leq$ 1000 mg/L. For human health risk assessment purposes, a water consumption rate of 2L/day is assumed. Thus, for drinking water containing 500 mg/L of sodium chloride, a sodium chloride intake of 1000 mg/day from water could be assumed.

An adult acute toxicity value for salt has been identified as an intake of $\geq$ 35,000 mg (35g) in one day (NAS 1980). Symptoms include vomiting, ulceration of the gastrointestinal tract, muscle weakness and renal damage, leading to dehydration, metabolic acidosis and severe peripheral and central neural effects. If this intake is a one-time event, it can be treated and full recovery is possible.

TABLE 4-3
WATER QUALITY GUIDE FOR LIVESTOCK AND POULTRY USES

Water Salinity, EC (dS/m) (mg/L)	Rating	Remarks
<1.5 (<1,200 mg/L)	Excellent	Usable for all classes of livestock and poultry.
=>1.5 - 5.0 (=>1,200 - 4,000 mg/L)	Very Satisfactory	Usable for all classes of livestock and poultry. May cause temporary diarrhea in livestock not accustomed to such water; watery droppings in poultry.
>5.0 - 8.0 (>4,000 - 6,400 mg/L)	Satisfactroy for Livestock	May cause temporary diarrhea or be refused at first by animals not accustomed to such water.
	Unfit for Poultry	Often causes watery feces, increased mortality and decreased growth, especially in turkey.
>8.0 - 11.0 (>6,400 - 8,800 mg/L)	Limited Use for Livestock	Usable with reasonable safety for dairy and beef cattle, sheep, swine and horses. Avoid use for pregnant or lactating animals.
	Unfit for Poultry	Not acceptable for poultry.
>11.0 - 16.0 (>8,800 - 12,800 mg/L)	Very Limited Use	Unfit for poultry and probably unfit for swine. Considerable risk in using for pregnant or lactating cows, horses, sheep, or for the use of the young of these species. In general, use should be avoided although older ruminants, horses, poultry and swine may subsist on waters such as these under certain conditions.
>16.0 (>12,800 mg/L)	Not Recommended	Risks with such highly saline water are so great that it cannot be recommended for use under any conditions.

Source: Ayers and Wescot 1994
Salinity values (mg/L) in parentheses are added and approximated on the basis of 1 dS/m = 800 mg/L of NaCl.

No specific adult chronic toxicity value for salt has been identified. The primary adverse effect of increased sodium chloride in the diet is increased blood pressure, which is a major risk factor for cardiovascular-renal diseases. There is, however, a well-recognized heterogeneity in blood pressure response from different population groups. The most sensitive groups are older persons, African Americans, and individuals with hypertension, diabetes or chronic kidney disease. These groups are affected at intakes that would not cause an effect in the rest of the population. The Institute of Medicine of the National Academies (2004) has recently set a recommended upper limit (UL) of 5800 mg/day of sodium chloride, although they recognized that prolonged exercise in a hot environment could actually result in an increased need for sodium chloride above this level due to sweat losses.

CDOT will incorporate information on the adverse effects on dietary salt into the overall risk-based approach to groundwater. This approach will include multiple steps:

1. How much salt might be in the water (estimate)?
2. For what purpose is the groundwater being used (irrigation, stock watering, domestic use, drinking)?
3. How much salt is actually in the water (well testing)?
4. For groundwater that may be used as drinking water at a consumption rate of 2L/day, what percentage of dietary salt could be attributable to groundwater?
5. Could adverse impacts be related to the actual use of groundwater tested in Step Three (e.g., at a consumption rate of 2L/day, how much salt would the groundwater contribute to the overall salt intake rate in a typical diet)?

A guideline of 500 mg/L of sodium chloride in groundwater is proposed. This guideline would be used within the overall salt pile facilities ranking system as follows:

1. Salt Pile Facility Ranking Process Step One used to prioritize sites based on a qualitative estimate of vulnerability of media (soil, surface water, groundwater) to impacts from salt pile facilities. Specific potential concentrations of sodium chloride in groundwater would not be estimated.

2. Salt Pile Facility Ranking Process Step Two is used to prioritize sites based on estimated vulnerability of receptors to media (soil, surface water, groundwater) potentially impacted from salt pile facilities. This step includes site-specific field observations related to potential receptors as noted in the Step Two Questions. Actual or potential groundwater receptors identified, but no groundwater testing.
3. Salt pile facilities with high potential receptor vulnerability scores undergo site-specific investigations to measure actual impacts in terms of soil and surface water conductivity. Sodium chloride concentrations in groundwater would be measured. Groundwater with a sodium chloride concentration $\geq$ 500 mg/L attributable to a salt pile facility, and currently or likely to be used as a drinking water source, would be prioritized for source remediation and potentially for remediation at the point of use, depending on site-specific circumstances

It should be noted that currently, 96% of extracted groundwater in Colorado is used for agriculture (Colorado Foundation for Water Education 2004). Domestic use of groundwater only occurs in a few small rural communities or private wells. Thus, CDOT's approach to groundwater could be similar to the Colorado Department of Agriculture's agricultural chemicals program, i.e., voluntary BMPs to minimize risk to groundwater (Colorado Foundation for Water Education 2004). At CDOT salt pile facilities where use of groundwater is a potential concern, BMPs would be combined with site-specific risk assessment.

5.0 PILOT TEST

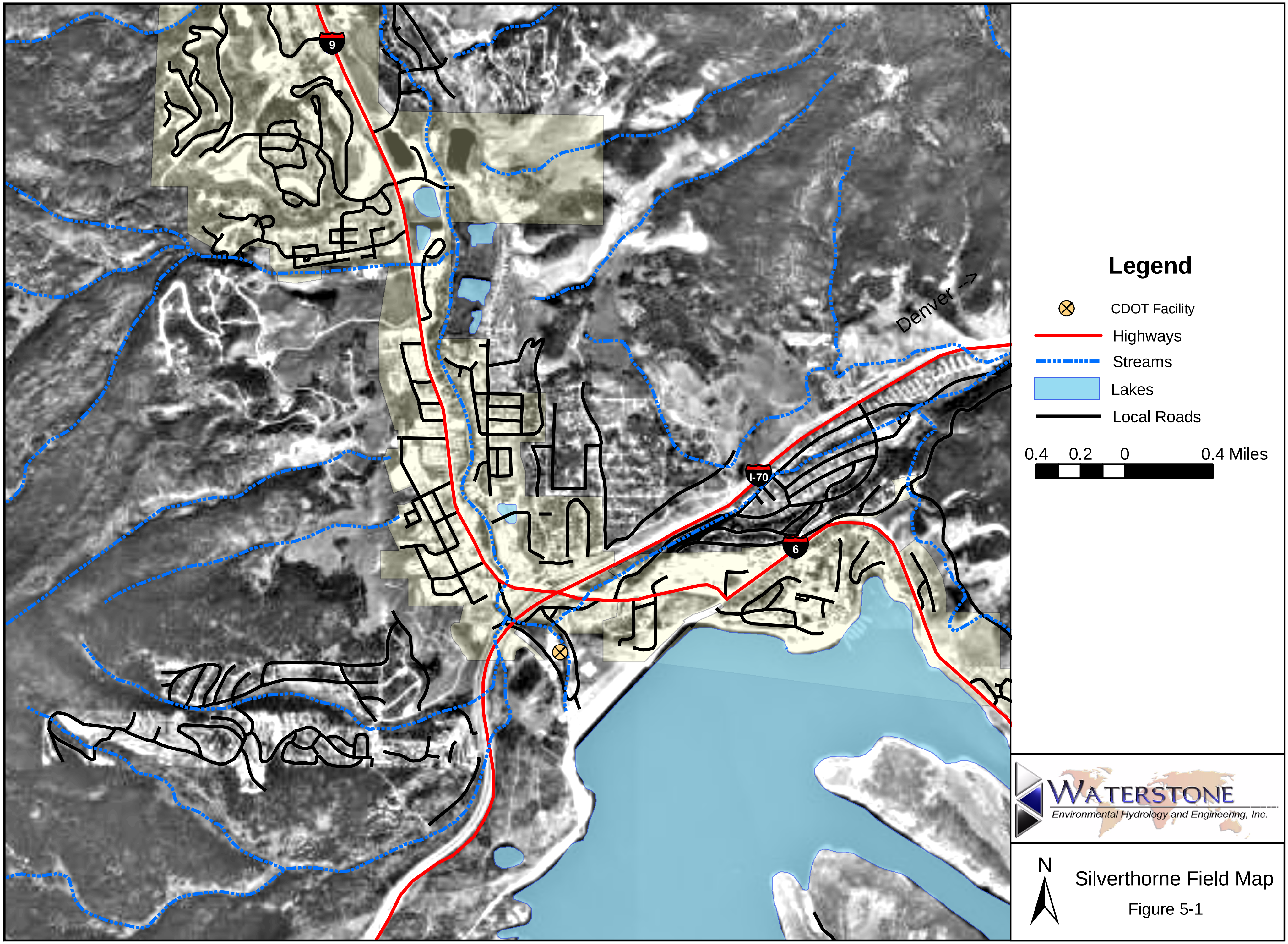
A site visit was conducted at the Silverthorne facility to pilot test the salt pile facility ranking system in the field. More specifically, the questions used in both Steps One and Two were evaluated for applicability, inclusiveness, and ease of completion.

The Silverthorne facility is located west of and adjacent to the Blue River, which is used for trout fishing and is fed by the Lake Dillon dam. The river is within 100 feet of the facility and is both adjacent and downgradient. The Silverthorne facility is also bordered by downgradient wetlands to the west and is ¼ mile north of an upgradient horse arena. The Silverthorne facility was chosen because it is a high usage facility, has a history of $MgCl_2$ releases, and has a high number of downgradient receptors.

5.1 Methods

Prior to the pilot test an informal phone interview was conducted with the facility manager to obtain background information on the site and the surrounding area as well as to setup logistics for the site visit. In addition an area and site map was created, as illustrated in Figures 5-1 and 5-2. Equipment for the visit included a water conductivity meter, a Brunton compass, pH tape, a thermometer, a container for a grab sample, measuring tape, area map, and a water level meter.

At the beginning of the pilot test two facility managers conducted a walking tour of the facility perimeter with Waterstone personnel and identified relevant areas and locations such as wells, previous spills, and storage areas. The managers also supplied additional information beyond the initial phone interview including management practices, mitigation measures to reduce migration of salt off-site, and site groundwater testing. Waterstone personnel then conducted a walking tour of the site boundary and adjacent off-site areas to survey potential receptors and the potential for off-site contamination. Upon completion of the tour, measurements were taken of depth to groundwater for wells on and off site, distances between wells. Finally, conductivity measurements were taken for the onsite well and for the Blue River at multiple locations.


9
I-70
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CDOT Facility
Highways
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0.4 0.2 0 0.4 Miles
WATERSTONE
Environmental Hydrology and Engineering, Inc.
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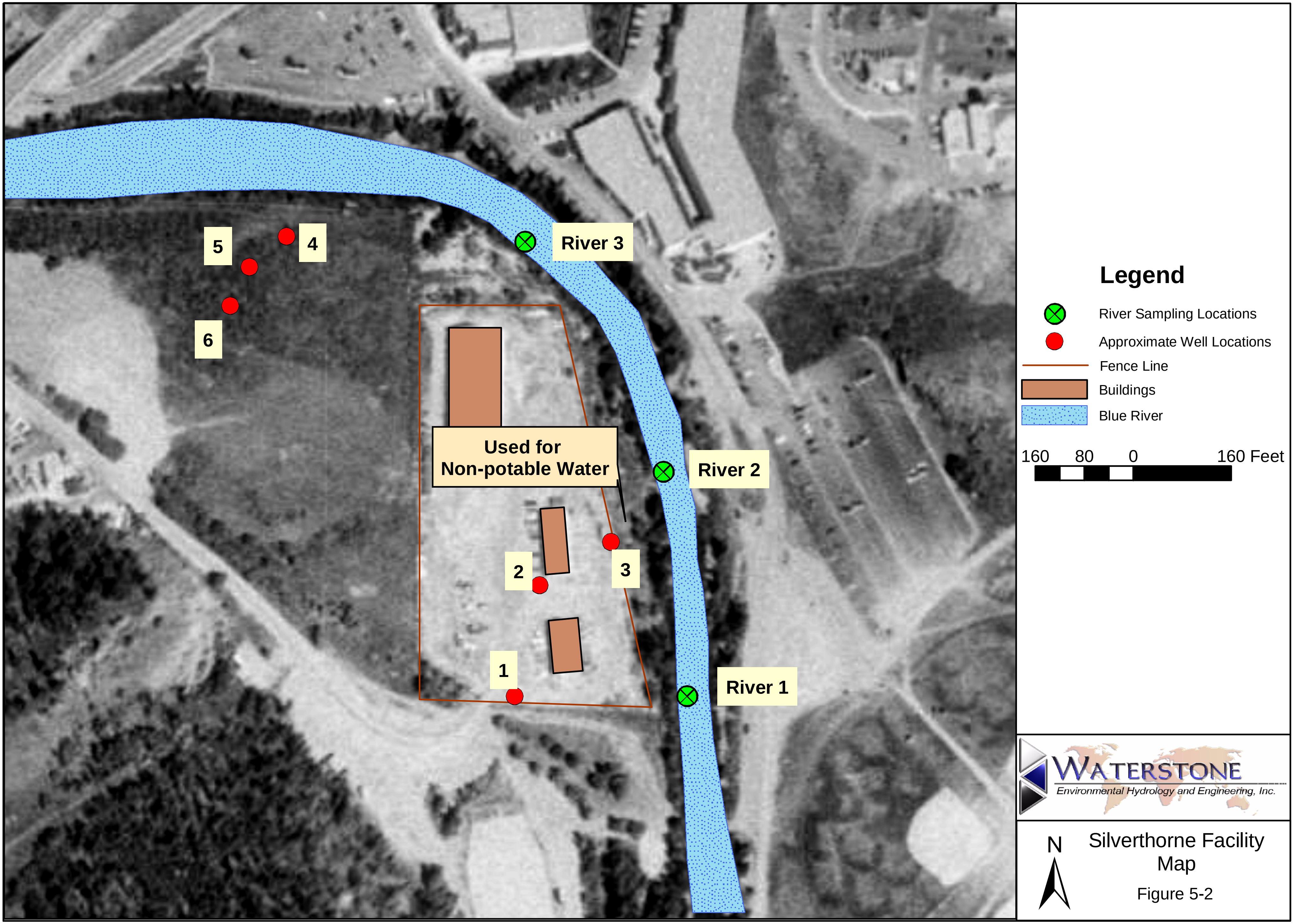
Silverthorne Field Map
Figure 5-1


River 3
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River Sampling Locations
Approximate Well Locations
Fence Line
Buildings
Blue River
160 80 0 160 Feet
WATERSTONE
Environmental Hydrology and Engineering, Inc.
N
Silverthorne Facility
Map
Figure 5-2

5.2 Results

The site visit resulted in an assessment of the “desk-top” results for Step One questions for the Silverthorne facility, some general site observations, and the completion of the Step Two questionnaire and subsequent ranking of the Silverthorne site. These results are discussed below.

5.2.1 Assessment of the Step One Results for the Silverthorne Facility After conducting the facility test, it was determined that several ranges of the vulnerability scores had to be modified to provide a more accurate ranking for the facilities. Multiple questions were added as well that were not originally conceived prior to the pilot test. The most profound change was replacing the precipitation category that existed at the time with a climate category that captures average snowfall in addition to average precipitation and temperature. Prior to these changes the Silverthorne facility scored 62 percent. After modifying the ranges, adding questions and modifying the precipitation category, the Silverthorne facility scored 60 percent, which categorizes the facility as a medium priority site.

5.2.2 General On-Site Observations During the site tour several observations were made: There was significant soil staining on site from salt, especially along the eastern edge but inside an existing berm.

- A path of water was leading from the center of the site towards the east.
- Dead vegetation existed just outside the perimeter of the facility on the northeast corner.
- Near the dead vegetation at the northeast corner was an overflow path from the edge of the facility down to the Blue River.
- The ground slope was less than 5 degrees on site but greater than 15 degrees off-site and within ¼ mile.

In addition to the observations, samples were taken of six wells and three areas along the Blue River. Three of the wells were on site and one of the three, located along the east fence was used as a non-potable source for the bathroom. The other three wells were within 100 feet of each other offsite and located northwest of the facility in the wetlands. Tables 5-1 and 5-2 below summarize the results for depth to water and water quality.

Table 5-1 - Wells and Depth to Groundwater - Silverthorne		
Well	Location	Depth to Water (feet)
1	south edge near entrance	20.64
2	central area of facility	19.45
3	east central area of facility	19.42
4	off site	11.8
5	off site	5.8
6	off site	5.3

Table 5-2 - Water Quality - Silverthorne				
Sample	TDS (mg/L)	Conductivity (µs/cm)	pH	Temperature (°C)
Well 3	375	336	7	7.9
River 1	383	344		5.1
River 2	382	338	7	6.4
River 3	374	337		7

5.2.3 Step Two Evaluation of the Silverthorne Facility Table 5-3 includes the results of Step Two.

5.3 Recommendations for Site Visits

The ability to complete Step Two conveniently and accurately depends on several factors. It is recommended that an environmental technician perform the site survey. This person should have a basic knowledge of vegetation and land use. It is also helpful for the surveyor to interview facility management to understand the historical background of the site. The surveyor should

TABLE 5-3
STEP 2 RESULTS - SILVERTHORNE

Environmental Factor	Low	Receptor Vulnerability Score			High
	1	2	3	4	5
Groundwater					
▪ Distance to nearest downgradient gw well used for human consumption (feet)	>1,000	>600≤1,000	>400≤600	>200≤400	≤200
▪ Proximity to downgradient gw well for livestock (feet)	>1,000	>600≤1,000	>400≤600	>200≤400	≤200
▪ Proximity to downgradient gw well for agriculture (feet)	>1,000	>600≤1,000	>400≤600	>200≤400	≤200
▪ Average depth to gw onsite of facility (feet)	>40	>30≤40	>20≤30	>10≤20	≤10
▪ Average depth to gw offsite w/in 1500 ft downgradient of facility (feet)	>40	>30≤40	>20≤30	>10≤20	≤10
▪ Water quality in nearest downgradient or onsite well (TDS) (mg/L)	≤250	>250≤500	>500≤1,000	>1,000≤3,000	>3,000
▪ Water quality in nearest upgradient well (TDS) (mg/L)	>3,000	>1,000≤3,000	>500≤1,000	>250≤500	≤250
Surface Water					
▪ Proximity to downgradient lake or pond (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Proximity to downgradient river or stream (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Proximity to downgradient wetland (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Water conductivity in nearest downgradient surface water body within ¼ mile (dS/cm)	None	≤4	>4≤7	>7≤10	>10
▪ Water conductivity in nearest upgradient surface water body within ¼ mile (dS/cm)	>10	>7≤10	>4≤7	≤4	none
▪ Slope of ground from site to lowest point downgradient within ¼ mile (degrees)	≤3	>3≤6	>6≤10	>10≤15	>15
▪ Evidence of erosion to any surface water body	None	Some	Moderate	Significant	Severe

▪ Aquatic organisms in nearest downgradient surface water body	None	Warm water species	Mixed	Limited cold water species	Cold water species
▪ Proximity to downgradient surface water feature used for agricultural irrigation or livestock watering (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Agricultural irrigation use of nearest downgradient surface water w/in ¼ mile	None	Pasture	Grains	Horticulture	Vegetables and fruit
▪ Livestock use of nearest downgradient surface water w/in ¼ mile	None	Minimal livestock use	Sheep, horses, and beef cattle	Dairy cattle and swine	Chickens and turkeys
Soil					
▪ Evidence of soil staining off-site	None	Some	Moderate	Significant	Severe
▪ Vegetation type w/in ¼ mile surrounding the site	Alkali grassland	Pasture/ Grassland	Pinyon/ Juniper	Riparian/ Crops	Pine/ Fir
▪ Evidence of vegetation impacts	None	Some	Moderate	Significant	Severe
▪ Proximity to downgradient agricultural use (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Proximity to downgradient livestock use (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Proximity to downgradient endangered plants (feet)	>2,000	>1,000≤2,000	>600≤1,000	>300≤600	≤300
▪ Soil conductivity off-site and downgradient w/in 1500 ft (dS/m)	≤5	>5≤10	>10≤15	>15≤20	>20

also have the necessary equipment to perform the survey and the knowledge to use the equipment. A suggested list of items includes:

- A water conductivity meter that performs both water conductivity and TDS measurements
- A Brunton compass to perform ground slope measurements
- A thermometer to measure temperature when conductivity and TDS are measured
- A container for water samples for water quality tests
- Measuring tape
- An area map for estimating distances that are too far to measure in the field
- A water level meter

6.0 RANKING TOOL AND USER GUIDE

The ranking tool is a Microsoft Access 2000 based, user-friendly database that walks users through Steps One and Two of the ranking process through a graphic user interface (GUI).

In Step One, facilities are pre-scored and ranked base on the information gathered from the GIS survey. The user can choose any facility through the Facility Selector box and see that facility's scores. Information was gathered for the media and climate categories discussed in Section 3.1. Each category's composite score is calculated as the percentage of vulnerability out of 100, with a score of 100 having maximum scores for each question. The final average score for each facility is based on an average of the category's composite scores. The final average score determines whether the facility is a low, medium or high priority facility. Facilities with a score from 0 – 51 are low, 52 – 62 are medium and 63 – 100 are high. High priority facilities prompt the user to proceed to Step Two.

In Step Two, the user is prompted to answer questions specific to the site for groundwater, surface water, and soil. The scoring is identical to Step One with categories having composite scores based on a percentage and a total average score based on an average of the category's composite scores. The program automatically calculates the final average score and if the facility has a high priority, prompts the user to proceed to Step Three, where an onsite investigation is required. Facilities with a score from 0 – 45 are low, 46 – 65 are medium and 66 – 100 are high.

A full description of the tool with a user's guide is available digitally in Appendix C.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

A risk-based salt pile facility ranking system is a valid approach for CDOT and is supported by both regulatory risk assessment guidance and the scientific literature. CDOT salt pile maintenance facilities are located in a wide variety of environments. These environments present very different risks in terms of the potential for salt to migrate off-site. In addition, the ecological and agricultural receptors in the vicinity of these facilities and their sensitivity to salt vary widely. Finally, these facilities also vary significantly in their proximity to potential drinking water wells. These variations mean that the potential risks from environmental salt need to be evaluated on a facility-specific basis.

This research provides a structured, scientifically-based procedure for ranking and evaluating the potential risks from salt piles to human health and the environment. This procedure will allow CDOT to address the facilities that pose the greatest potential risk first and to identify the nature of that risk to target further investigations and remediation.

This research also provides a scientific basis for identifying and evaluating toxicological risks associated with the potential consumption of salt-contaminated drinking water. Clearly, at any salt concentration above 1000 mg/L, taste would prevent any significant consumption. However, it is also clear that potential consumption of water with salt concentrations less than 1000 mg/L would not present an imminent hazard. This fact, combined with an investigation to determine whether actual consumption of salt-contaminated groundwater is occurring, gives CDOT the opportunity to manage and mitigate salt-contaminated groundwater in a cost-effective manner.

7.2 Recommendations

The following are a list of recommendations for further study and successful tool use:

1. Maintenance of Tool

The tool must be maintained over time to incorporate new sites, new data input, and features that increase the value of the tools use. A Maintenance Plan should be designed and implemented for the future updates of the tool.

2. Maintenance of Databases

The raw data in the databases that the tool relies on will need to be updated through time. This will occur with new sites and old. An example of the updates may be, but limited to, well locations, proximity to receptors, changes in stream or surface water body locations, and changes in climate that require more salt to be used.

3. Additional Pilot Studies

Only one Pilot Study was performed. Although the results were within the expected ranges for ranking there should be an additional 3 tests performed in different terrains and receptor environments.

4. Additional Software Features

Additional coding should be added to allow the tool to self-install off of the CD-ROM for easier installation. Coding should also be added to allow the program to be used on computers with different monitor resolutions. A map library should be incorporated into the tool to allow users to view the maps that correspond to the data in Step One. A reporting feature should be added to allow users to print facility results in a printer friendly report format.

5. An Implementation Plan for Step Three – Site Investigation

Step Three is a Site Investigation, which requires on-site sampling, lab analysis, and technical oversight and management. It is suggested that a site investigation implementation plan be developed so in the event of high Step Two ranking, the plan is in place for preparing budget and mobilization.

6. An Implementation Plan for Remediation

In step with number 5 above, a Remediation Plan can be developed so that the plan is approved and in place for preparing budgets, mobilization, and monitoring.

7. An Operation and Reporting Plan

In step with number 6 above, an operations and reporting plan should be developed that formally posts the ranking of each site, the proposed remedy, and action plans. There should be a regularly scheduled update of the site locations each year to capture new, abandoned, sold, or remedied sites.

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Acronyms

BMP – Best Management Practice

CDOT – Colorado Department of Transportation

CDPHE – Colorado Department of Public Health and Environment

CEPA – Canadian Environmental Protection Act

COMA – Committee on Medical Aspects of Food Policy

DEQ – Department of Environmental Quality

DOT – Department of Transportation

EPA – Environmental Protection Agency

GUI – Graphic User Interface

MDEP – Maine Department of Environmental Protection

$MgCl_2$ – Magnesium Chloride

MGS – Maine Geological Survey

NaCl – Sodium Chloride

NAS – National Academy of Sciences

ppm – Parts Per Million

TDS – Total Dissolved Solids

UL – Upper Limit

APPENDIX A

Proposal

SCOPE OF WORK

12/18/03

REMEDIATION RANKING SYSTEM FOR SALT CONTAMINATED SOIL

1.0 BACKGROUND

Many of CDOT's maintenance yards are contaminated with sodium chloride (NaCl) after decades of use of sand/salt piles that were stored in the yard exposed to the elements. More recent leaks and spills from magnesium chloride ($MgCl_2$) salt tanks stored above ground have contaminated the local soil. Both forms of salt will be the subjects of this research. The current regulatory approach from CDPHE is to determine a background level of both salts in the immediate area and require CDOT to remediate the contaminated soil down to a level that is no more than three times background concentrations. CDOT recently spent $158,000 excavating the on-site "contaminated" portion of the maintenance yard at Soda Lakes (on Hampden in Lakewood) and still has the off-site impact to deal with. Estimated cost to remediate up to 200 maintenance yards ranges from $10 million to $40 million.

2.0 OBJECTIVES OF THE STUDY

This research will produce a preliminary ranking system utilizing a risk-based model that is protective of human health and the environment regarding salt contamination in soil, groundwater and surface water. The basic objective is to move away from a highly subjective background-based standard for remediation and move toward a toxicological, risk-based approach that is based on sound science and meets statutory requirements.

3.0 EXPECTED BENEFITS OF THE STUDY

The current generic approach to cleanup and remediation of salt-contaminated soil is very expensive and is not linked to site-specific protection of human health and the environment. A site-specific, risk-based approach will provide a strategy for allocating limited resources and will be the basis of a planning process for the cleanup of sites in an expedient, protective and cost-effective manner. CDOT will be able to use a broad-based and consistent, risk-based model, designed to be customized by physiographic region and county for key site parameters, as a screening tool to:

- Rank the priority of a site for further study,
- Conduct a preliminary site-specific screen at high priority sites, and
- Evaluate the extent of potential contamination for mitigation or remediation purposes.

It is anticipated that this risk-based approach will cut remediation costs substantially.

4.0 RESEARCH APPROACH

TASK 1 DATA COMPILATION

A. Literature Review

A summary of approaches to dealing with environmental contamination caused by salt piles will be compiled. State DOTs with developed approaches include Maine, Minnesota and New York. In addition, Canada has determined that road salt is a highly toxic contaminant and has developed a rigorously regulatory program to deal with this issue. The product for this task will be a matrix comparing the regulatory approaches for 3-6 states and Canada and 3-5 pages of text summarizing the major common features of each strategy.

B. Colorado Data Acquisition

The ability to apply site-specific information in the evaluation of a salt pile will benefit CDOT. This task will assemble easily available information on geology, physiographic regions, soil types, water bodies, and topography to develop look-up tables and graphical input that will be part of the site ranking methodology. Some of the information for the look up tables will be region-specific, based on the five major physiographic regions of Colorado: eastern plains, front range, rocky mountains, northwestern slope and southwestern slope. Some of the information for the look up tables will be county-specific, based on existing Soil Conservation Service (SCS) data. The tabular information would be entered into an Access database. To the extent that digital information is available, GIS coverages will be assembled, including a digital map with all of the salt pile locations. For counties where SCS information is not available, future users will need to acquire that information or develop a site-specific assumption.

TASK 2 TOXICITY EVALUATION

One of the primary goals of this research will be to establish toxicity-based, site-specific remediation goals for soil, vegetation, groundwater and surface water. Risk-based remediation goals will be developed for magnesium and sodium chloride based on potential impacts to soil and subsequent, site-specific estimated impacts to groundwater and surface water via the soil pathway.

Information to be considered in developing risk-based remediation goals will include whether complete pathways may exist from salt storage areas to potential receptors, existing toxicological information and existing regulatory guidelines.

TASK 3 RANKING METHODOLOGY

The base map and tabular information developed in Task 1, the risk-based model developed in Task 2, and site-specific salt pile location observations will be integrated into a three step process for a user to evaluate the potential environmental impact of a salt pile in a specific location.

Briefly, these three steps will include the following:

- **Step One:** A simple, site-specific observational step that includes limited site-specific information and data and partial use of the model developed in Task 2 to develop a preliminary site ranking number on a scale of, e.g., 1-5. Based on the information compiled for this step, relatively low-cost remediation strategies may be identified for some sites. Sites that score from 1-3 would move to Step Two. Low-ranking sites may be tagged for limited presumptive control measures, institutional controls and/or covenants based on the results of this step.

- **Step Two:** This step would build on Step One by developing equations that permit the input of site-specific variables and county-specific, and region-specific variables from the look-up tables to estimate potential concentrations in soil, groundwater and surface water. The results of Step Two would include information on potential receptors and whether exposure pathways might be complete, as well as estimated magnesium, chloride, and sodium concentrations in the soil column beneath the pile site, and in groundwater. These estimated concentrations would be compared to the risk-based remediation concentrations developed in Task 2. This process would result in a final site ranking number, e.g., 1-3. As in Step One, based on the information compiled for this step, relatively low-cost remediation strategies may be identified at this point for some sites. Sites that score from 1-2 would move to Step Three.

- **Step Three:** Sites with a ranking of 1 or 2 would need to develop a conceptual site investigation plan to identify mitigation or remediation strategies that CDOT could consider for the site. Strategies could include a range of options from removing pathways to actual soil removal. Designing the site investigation will only be briefly discussed in this methodology.

TASK 4 USER INTERFACE TOOL

The user interface tool would consist of easy to use menus, linked to an Access database that would permit the user to complete Steps One and Two. As discussed above, the input variables would include both site-specific observations and data and information for tables developed in Task 1. Step Three, designing the site-specific investigation, will only be briefly discussed in the user guide.

TASK 5 PILOT TESTING

The ranking methodology and the user interface tool will be used to test one location specified by CDOT. CDOT personnel at the selected test location and Waterstone will collect the information needed to test the ranking methodology.

TASK 6 PROJECT MANAGEMENT AND MEETINGS

Four major meetings with CDOT are anticipated as follows:

- Start up meeting to introduce key personnel and review the details of the proposed approach
- Mid-project meeting to present draft findings, discuss the ranking formulas and preliminary results, elicit feedback from CDOT, and resolve any issues prior to the Pilot Test
- Draft presentation on the results of the Pilot Test
- Delivery and presentation of final product

This task also includes monthly project status reports to CDOT, conference calls, emails and any additional requested communication with CDOT.

TASK 7 FINAL REPORT AND USER GUIDE

The final report will document the objective, methodology, and reference data used to develop the ranking methodology, including the look-up tables and the risk-based model. In addition, the final report will include a user guide for implementing the ranking methodology for Steps One and Two.

5.0 ASSUMPTIONS AND CAVEATS

This scope of work and the associated budget includes the following assumptions and caveats:

- Specific details of the technical approach and schedule will be developed in consultation with CDOT
- The selected pilot test site will be located in the front range
- Prior to full scale implementation of this methodology, a larger scale pilot test and review by CDOT personnel will be needed
- Waterstone has not been tasked to evaluate the cyanide that may occur in the salt piles

APPENDIX B

Toxicity Study

1.0 INTRODUCTION

One of the primary goals of the CDOT Salt Piles research is to establish toxicity-based, site-specific guidelines for potentially salt-impacted soil, groundwater and surface water. Regional guidelines are developed for sodium chloride and TDS or conductivity based on potential impacts to soil and subsequent, site-specific estimated impacts to groundwater and surface water via the soil pathway for vegetation and aquatic life in five regional physiographic areas in Colorado. In addition, guidelines are also developed for the use of surface or groundwater for irrigation and stock watering and for the use of groundwater as drinking water. These guidelines will be one element in the site-specific aspect of the overall site ranking system. The ranking system also includes site-specific exposure pathway observations for individual salt pile facilities.

Information considered in developing regional guidelines includes:

- Current regulatory guidelines,
- Available toxicological information, and
- Regional ecosystem information.

Sections 2 and 3 summarize the information on current regulatory guidelines and toxicological information for ecological and agricultural receptors, for use of groundwater as drinking water and a risk-based approach for evaluating potential groundwater impacts. Section 4 presents a physiographic region map for Colorado and the basis for the designated regions. Section 5 integrates the toxicity information and the physiographic information and proposes regional toxicity value ranges for ecological and agricultural receptors. Section 6 discusses the type of site-specific exposure pathway observations that will be incorporated in the overall scoring system for salt pile facilities.

2.0 CURRENT REGULATORY GUIDELINES

The primary constituents in CDOT salt piles are sodium, magnesium and chloride. Only a few regulatory guidelines exist for these substances.

- · Secondary MCL for drinking water (SMCL): 250 mg/L chloride
- · Secondary MCL for drinking water (SMCL): 500 mg/L TDS (salinity)
- · Ambient Water Quality Criteria (AWQC): 230 mg/L chloride

It should be noted that the drinking water guidelines are based on taste, not toxicity. Toxicity information for salt in drinking water will be discussed in Section 3.3.

3.0 SALT TOXICITY/TOLERANCE INFORMATION

Much of the information on salt toxicity for both soil and surface water comes from the agricultural literature and from dated references going back to the 1970's and earlier. In this literature, salt toxicity is usually defined in terms of tolerance to electrical conductivity (EC), typically measured as deciSiemens per meter (dS/m), not in terms of mg/kg or mg/L of NaCl or $MgCl_2$ or of specific ions. In addition, the sources of more recent information, such as agricultural and university extension services in Colorado and Utah, also employ dS/m as the primary unit of measurement .

This agricultural literature was used to determine EC values for soil salinity tolerance for vegetation (Section 3.1) and EC values for irrigation and stock water salinity tolerances (Section 3.2). For surface water, the literature used to develop Ambient Water Quality Criteria (AWQC), expressed in mg/L, was also utilized.

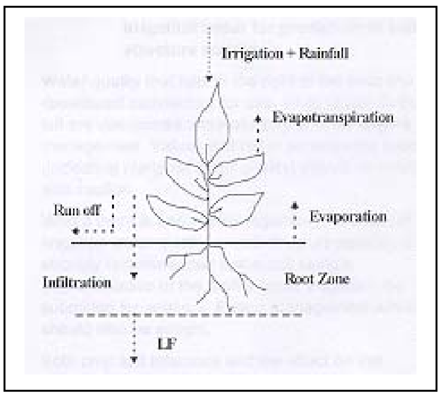
The potential use of groundwater as drinking water and as irrigation water has been considered. Toxicity values for salt in drinking water are discussed in Section 3.3. Groundwater as a potential source of salts for surface water is considered in the transport estimate portion of this study.

Based on a previous study conducted by CDOT demonstrating the lack of toxicity and inert characteristics of magnesium, specific guidelines for magnesium have not been developed (Lewis 1997). The presence of magnesium, however, would contribute to TDS and conductivity values.

3.1 Soil

3.1.1 Mechanisms of Soil Toxicity

Soil salinity is a measure of the total amount of soluble salt in soil. As soil salinity levels increase, the ability of plants to extract water and nutrients from the soil is reduced. Plant roots absorb water and nutrients from the soil through osmosis, the movement of water from areas of high concentration to low concentration. As soil salinity increases, water and associated nutrients do not move as easily from the soil into the roots. In other words, excess salt in the soil results in more water being held in the soil and, therefore, water is less available for plant uptake. Salinity problems are caused by the accumulation of soluble salts in the root zone, illustrated in the figure to the left. In sandy soils, rapid infiltration through the soil tends to leach salts from the root zone, while heavy clay soils may lead to accumulation of salts in the root zone.



Plant species vary considerably in how well they tolerate saline soils. However, when soil salinity exceeds a plant's tolerance, growth reduction, stunting and eventually death occur. In addition, some elements, such as sodium and chlorine, can have specific toxic effects on plants, however, Waterstone found no specific literature on that subject beyond the literature cited in this report.

3.1.2 Soil Tolerance Values

A variety of classifications are used to segregate plants on the basis of their tolerance to soil salinity. As mentioned above, soil salinity is typically measured in deciSiemens per meter (dS/m), units of conductivity. In general, most plant classification systems are approximately as follows:

Salt Tolerance	Soil Salinity(dS/m)	Comments
Very high	16-20	Only a few, very tolerant plants will grow at these levels of soil salinity including tall and western wheatgrass, saltgrass, and alkali grass.
High	8-16	Only tolerant plants will grow at these soil salinity levels including sweet clover, crested and slender wheatgrass, various saltbushes, rabbitbrush, creosote, ephedra, pinyon pine and juniper.
Moderate	4-8	Growth of many plants will be restricted at these levels of soil salinity including some vegetable crops, aspen and cottonwood trees, and spruce and fir trees.
Low	2-4	Growth of sensitive plants will be restricted at these levels of soil salinity including some species of clover, fescue, bluegrass, most vegetable and fruit crops, maple trees, lindens, and dogwoods
Very low	<2	Most plants will have little or no adverse response at this level of soil salinity

Table B3-1 lists soil salinity threshold and tolerance values from the US Department of Agriculture (USDA) and Colorado State University (CSU) for a variety of crop, ornamental, and native plant species. In general, the values in Table B3-1 reflect the classifications in the table above. For example, fruit and vegetable crops have a low tolerance for saline soil while pasture and forage species have a moderate to high tolerance.

Table B3-1
Vegetation Soil Salinity Threshold and Tolerance Values Based on Chronic Studies

Receptor	Common Name	Classification[1]	Salinity (dS/m)	Endpoint[2]	Reference
Helianthus tuberosus	Artichoke	Crop	0	Threshold	USDA 2004
Brassica Rapa	Turnip	Crop	1	Threshold	USDA 2004
Phaseolus vulgaris	Bean	Crop	1	Threshold	USDA 2004
Phaseolus vulgaris	Bean	Crop	1	Threshold	USDA 2004
Daucus carota	Carrot	Crop	1	Threshold	USDA 2004
Fragaria sp.	Strawberry	Crop	1	Threshold	USDA 2004
Solanum Melongena esculentum	Eggplant	Crop	1	Threshold	USDA 2004
Allium Cepa	Onion	Crop	1	Threshold	USDA 2004
Raphanus sativus	Radish	Crop	1	Threshold	USDA 2004
Lactuca sativa	Lettuce	Crop	1	Threshold	USDA 2004
Trifolium hybridum	Clover, alsike	Crop	2	Threshold	USDA 2004
T. alexandrinum	Clover, Berseem	Crop	2	Threshold	USDA 2004
Trifolium repens	Clover, ladino	Crop	2	Threshold	USDA 2004
T. pratense	Clover, red	Crop	2	Threshold	USDA 2004
T. fragiferum	Clover, strawberry	Crop	2	Threshold	USDA 2004
Alopecurus pratensis	Foxtail, meadow	Crop	2	Threshold	USDA 2004
Dactylis glomerata	Orchardgrass	Crop	2	Threshold	USDA 2004
Capsicum annuum	Pepper	Crop	2	Threshold	USDA 2004
Ipomoea Batatas	Sweet potato	Crop	2	Threshold	USDA 2004
Prunus Duclis	Almond	Crop	2	Threshold	USDA 2004
Rubus sp	Blackberry	Crop	2	Threshold	USDA 2004
Rubus ursinus	Boysenberry	Crop	2	Threshold	USDA 2004
Vitis sp.	Grape	Crop	2	Threshold	USDA 2004
Prunus domestica	Plum; Prune	Crop	2	Threshold	USDA 2004
Vicia Faba	Broadbean	Crop	2	Threshold	USDA 2004
Prunus armeniaca	Apricot	Crop	2	Threshold	USDA 2004
Zea mays	Corn	Crop	2	Threshold	USDA 2004
Linum usitatissimum	Flax	Crop	2	Threshold	USDA 2004
Saccharum officinarum	Sugarcane	Crop	2	Threshold	USDA 2004
Zea mays	Corn, sweet	Crop	2	Threshold	USDA 2004
Solanum tuberosum	Potato	Crop	2	Threshold	USDA 2004
L. esculentum var cerasiforme	Tomato, cherry	Crop	2	Threshold	USDA 2004
Citrus sinensis	Orange	Crop	2	Threshold	USDA 2004
Prunus Persica	Peach	Crop	2	Threshold	USDA 2004
Zea mays	Corn	Crop	2	Threshold	USDA 2004
Vigna radiata	Bean, mung	Crop	2	Threshold	USDA 2004
B. oleracea capitata	Cabbage	Crop	2	Threshold	USDA 2004
Apium graveolens	Celery	Crop	2	Threshold	USDA 2004
Citrus paradisi	Grapefruit	Crop	2	Threshold	USDA 2004
Medicago sativa	Alfalfa	Crop	2	Threshold	USDA 2004
Eragrostis sp.	Lovegrass	Crop	2	Threshold	USDA 2004
Spinacia oleracea	Spinach	Crop	2	Threshold	USDA 2004

Table B3-1
Vegetation Soil Salinity Threshold and Tolerance Values Based on Chronic Studies

Receptor	Common Name	Classification[1]	Salinity (dS/m)	Endpoint[2]	Reference
Trachelospermum jasminoides	Star jasmine	Crop	1-2	Threshold	USDA 2004
Cotoneaster congestus	Pyrenees cotoneaster	Crop	1-2	Threshold	USDA 2004
Mahonia Aquifolium	Oregon grape	Crop	1-2	Threshold	USDA 2004
Photinia x Fraseri	Photinia	Crop	1-2	Threshold	USDA 2004
T. turgidum	Wheat, Durum	Crop	2	Threshold	USDA 2004
Sphaerophysa salsula	Sphaerophysa	Crop	2	Threshold	USDA 2004
Sesbania exaltata	Sesbania	Crop	2	Threshold	USDA 2004
Lotus uliginosus	Trefoil, big	Crop	2	Threshold	USDA 2004
Vigna unguiculata	Cowpea	Crop	3	Threshold	USDA 2004
Cucumis sativus	Cucumber	Crop	3	Threshold	USDA 2004
Lycopersicon Lycopersicum	Tomato	Crop	3	Threshold	USDA 2004
E. triticoides	Wildrye, beardless	Crop	3	Threshold	USDA 2004
Sorghum sudanense	Sudangrass	Crop	3	Threshold	USDA 2004
Brassica oleracea botrytis	Broccoli	Crop	3	Threshold	USDA 2004
Oryza sativa	Rice,paddy	Crop	3	Threshold	USDA 2004
Vicia angustifolia	Vetch, common	Crop	3	Threshold	USDA 2004
Feijoa Sellowiana	Pineapple guava	Crop	2-3	Threshold	USDA 2004
Ilex cornuta	Chinese holly,cv. Burford	Crop	2-3	Threshold	USDA 2004
Rosa sp.	Rose, cv. Grenoble	Crop	2-3	Threshold	USDA 2004
Abelia x grandiflora	Glossy abelia	Crop	2-3	Threshold	USDA 2004
Podocarpus macrophyllus	Southern yew	Crop	2-3	Threshold	USDA 2004
Liriodendron Tulipifera	Tulip tree	Crop	2-3	Threshold	USDA 2004
Arachis hypogaea	Peanut	Crop	3	Threshold	USDA 2004
Cucurbita Pepo Melopepo	Squash, scallop	Crop	3	Threshold	USDA 2004
Agropyron sibiricum	Wheatgrass, standard crested	Crop	4	Threshold	USDA 2004
Festuca elatior	Fescue, tall	Crop	4	Threshold	USDA 2004
Beta Vulgaris	Beet, red	Crop	4	Threshold	USDA 2004
Phoenix dactylifera	Date palm	Crop	4	Threshold	USDA 2004
Hedera canariensis	Algerian ivy	Crop	3-4	Threshold	USDA 2004
Pittosporum Tobira	Japanese pittosporum	Crop	3-4	Threshold	USDA 2004
Nandina domestica	Heavenly bamboo	Crop	3-4	Threshold	USDA 2004
Hibiscus Rosa-sinensis	Chinese hibiscus	Crop	3-4	Threshold	USDA 2004
Viburnum Tinusm	Laurustinus, cv. Robustum	Crop	3-4	Threshold	USDA 2004
Arbutus Unedo	Strawberry tree, cv. Compact	Crop	3-4	Threshold	USDA 2004
Lagerstroemia indica	Crape Myrtle	Crop	3-4	Threshold	USDA 2004
Asparagus officinalis	Asparagus	Crop	4	Threshold	USDA 2004
Triticum aestivum	Wheat	Crop	5	Threshold	USDA 2004
Phalaris tuberosa	Hardinggrass	Crop	5	Threshold	USDA 2004
C. Pepo Melopepo	Squash, zucchini	Crop	5	Threshold	USDA 2004
Vigna unguiculata	Cowpea	Crop	5	Threshold	USDA 2004
Glycine max	Soybean	Crop	5	Threshold	USDA 2004
L. corniculatus tenuifolium	Trefoil, narrowleaf birdsfoot	Crop	5	Threshold	USDA 2004

Table B3-1
Vegetation Soil Salinity Threshold and Tolerance Values Based on Chronic Studies

Receptor	Common Name	Classification[1]	Salinity (dS/m)	Endpoint[2]	Reference
L. perenne	Ryegrass, perennial	Crop	6	Threshold	USDA 2004
T. turgidum	Wheat, Durum	Crop	6	Threshold	USDA 2004
Triticum aestivum	Wheat	Crop	6	Threshold	USDA 2004
Hordeum vulgare	Barley	Crop	6	Threshold	USDA 2004
Ligustrum lucidum	Glossy privet	Crop	4-6	Threshold	USDA 2004
Lantana Camara	Yellow sage	Crop	4-6	Threshold	USDA 2004
Bauhinia purpurea	Orchid tree	Crop	4-6	Threshold	USDA 2004
Magnolia grandiflora	Southern Magnolia	Crop	4-6	Threshold	USDA 2004
Buxus microphylla var. japonica	Japanese boxwood	Crop	4-6	Threshold	USDA 2004
Xylosma congestum	Xylosma	Crop	4-6	Threshold	USDA 2004
Pinus Thunbergiana	Japanese black pine	Crop	4-6	Threshold	USDA 2004
Raphiolepis indica	Indian hawthorn	Crop	4-6	Threshold	USDA 2004
Dodonaea viscosa	Dodonaea, cv. atropurpurea	Crop	4-6	Threshold	USDA 2004
Platycladus orientalis	Oriental arborvitae	Crop	4-6	Threshold	USDA 2004
Elaeagnus pungens	Thorny elaeagnus	Crop	4-6	Threshold	USDA 2004
Juniperus chinensis	Spreading juniper	Crop	4-6	Threshold	USDA 2004
Pyracantha Fortuneana	Pyracantha, cv. Graberi	Crop	4-6	Threshold	USDA 2004
Prunus cerasifera	Cherry plum	Crop	4-6	Threshold	USDA 2004
X Triticosecale	Triticale	Crop	6	Threshold	USDA 2004
Sorghum bicolor	Sorghum	Crop	7	Threshold	USDA 2004
Cynodon Dactylon	Bermudagrass	Crop	7	Threshold	USDA 2004
Beta vulgaris	Sugarbeet	Crop	7	Threshold	USDA 2004
A. cristatum	Wheatgrass, fairway crested	Crop	8	Threshold	USDA 2004
A. elongatum	Wheatgrass, tall	Crop	8	Threshold	USDA 2004
Gossypium hirsutum	Cotton	Crop	8	Threshold	USDA 2004
Hordeum vulgare	Barley	Crop	8	Threshold	USDA 2004
Syzygium paniculatum	Brush cherry	Crop	8	Threshold	USDA 2004
Leucophyllum frutescens	Ceniza	Crop	8	Threshold	USDA 2004
Carissa grandiflora	Natal plum	Crop	8	Threshold	USDA 2004
Pyrus Kawakamii	Evergreen Pear	Crop	8	Threshold	USDA 2004
Bougainvillea spectabilis	Bougainvillea	Crop	8	Threshold	USDA 2004
Pinus pinea	Italian stone pine	Crop	8	Threshold	USDA 2004
Callistemon viminalis	Weeping bottlebrush	Crop	6-8	Threshold	USDA 2004
Nerium oleander	Oleander	Crop	6-8	Threshold	USDA 2004
Chamaerops humilis	European fan palm	Crop	6-8	Threshold	USDA 2004
Cordyline indivisa	Blue dracaena	Crop	6-8	Threshold	USDA 2004
Rosmarinus officinalis	Rosemary	Crop	6-8	Threshold	USDA 2004
Pinus halepensis	Aleppo pine	Crop	6-8	Threshold	USDA 2004
Liquidamabar Styraciflua	Sweet gum	Crop	6-8	Threshold	USDA 2004
Hibiscus cannabinus	Kenaf	Crop	8	Threshold	USDA 2004
T. aestivum	Wheat	Crop	9	Threshold	USDA 2004
Cyamopsis tetragonoloba	Guar	Crop	9	Threshold	USDA 2004

Table B3-1
Vegetation Soil Salinity Threshold and Tolerance Values Based on Chronic Studies

Receptor	Common Name	Classification[1]	Salinity (dS/m)	Endpoint[2]	Reference
Delosperma alba	White iceplant	Crop	10	Threshold	USDA 2004
Drosanthemum hispidum	Rosea iceplant	Crop	10	Threshold	USDA 2004
Lampranthus productus	Purple iceplant	Crop	10	Threshold	USDA 2004
Hymenocyclus croceus	Croceum iceplant	Crop	10	Threshold	USDA 2004
Secale cereale	Rye	Crop	11	Threshold	USDA 2004
Parthenium argentatum	Guayule	Crop	15	Threshold	USDA 2004
Acer rubrum	Red Maple	VT	0	Tolerance	Swift 2004
Acer saccharinum	Silver Maple	VT	0	Tolerance	Swift 2004
Acer saccharum	Sugar Maple	VT	0	Tolerance	Swift 2004
Cercis canadensis	Eastern Redbud	VT	0	Tolerance	Swift 2004
Juglans nigra	Black Walnut	VT	0	Tolerance	Swift 2004
Plantanus acerifolia	London Plane	VT	0	Tolerance	Swift 2004
Sorbus aucuparia	European Mountain-Ash	VT	0	Tolerance	Swift 2004
Tilia americana	American linden	VT	0	Tolerance	Swift 2004
Tilia cordata	Littleleaf Linden	VT	0	Tolerance	Swift 2004
Abies balsamea	Balsam Fir	VT	0	Tolerance	Swift 2004
Pinus resinosa	Red or Norway Pine	VT	0	Tolerance	Swift 2004
Tsuga canadensis	Canadian Hemlock	VT	0	Tolerance	Swift 2004
Cornus racemosa	Grey Dogwood	VT	0	Tolerance	Swift 2004
Cornus stolonifera	Red-osier dogwood	VT	0	Tolerance	Swift 2004
Rosa	Rose	VT	0	Tolerance	Swift 2004
Alopecurus pratensis	Meadow foxtail	VT	0	Tolerance	Swift 2004
Festuca rubra	Red fescue	VT	0	Tolerance	Swift 2004
Festuca elatior	Meadow fescue	VT	0	Tolerance	Swift 2004
Poa pratensis	Kentucky Bluegrass	VT	0	Tolerance	Swift 2004
Trifolium pratense	Red clover	VT	0	Tolerance	Swift 2004
Trifolium repens	White clover	VT	0	Tolerance	Swift 2004
Quercus palustris	Pin Oak	VT	<= 2	Tolerance	Swift 2004
Malus species and cultivars	Apple and Crabapple	VT	<= 2	Tolerance	Swift 2004
Picea albies	Norway Spruce	VT	<= 2	Tolerance	Swift 2004
Pinus strobus	Eastern White Pine	VT	<= 2	Tolerance	Swift 2004
Pinus sylvestris	Scot's Pine	VT	<= 2	Tolerance	Swift 2004
Pseudotsuga menziesii	Douglas Fir	VT	<= 2	Tolerance	Swift 2004
Taxus cuspidata	Japanese Yew	VT	<= 2	Tolerance	Swift 2004
Chaenomeles speciosa	Flowering Quince	VT	<= 2	Tolerance	Swift 2004
Ligustrum vulgare	Common Privet	VT	<= 2	Tolerance	Swift 2004
Rosa rugosa	Rugosa Rose	VT	<= 2	Tolerance	Swift 2004
Viburnum opulus	High Bush Cranberry	VT	<= 2	Tolerance	Swift 2004
Catalpa speciosa	Northern Catalpa	VT	<= 4	Tolerance	Swift 2004
Celtis occidentalis	Hackberry	VT	<= 4	Tolerance	Swift 2004
Celtis reticulata	Netleaf hackberry	VT	<= 4	Tolerance	Swift 2004
Cercis occidentalis	Western Redbud	VT	<= 4	Tolerance	Swift 2004

Table B3-1
Vegetation Soil Salinity Threshold and Tolerance Values Based on Chronic Studies

Receptor	Common Name	Classification[1]	Salinity (dS/m)	Endpoint[2]	Reference
Fraxinus anomala	Singleleaf Ash	VT	<= 4	Tolerance	Swift 2004
Fraxinus excelsior	European Ash	VT	<= 4	Tolerance	Swift 2004
Fraxinus pennsylvanica	Green Ash	VT	<= 4	Tolerance	Swift 2004
Ginkgo biloba	Maindenhair Tree	VT	<= 4	Tolerance	Swift 2004
Koelreuteria paniculata	Goldenrain Tree	VT	<= 4	Tolerance	Swift 2004
Maclura pomifera	Osage-Orange	VT	<= 4	Tolerance	Swift 2004
Pyrus species	Pear	VT	<= 4	Tolerance	Swift 2004
Ulmus americana	American Elm	VT	<= 4	Tolerance	Swift 2004
Artemisia cana	Silver Sagebrush	VT	<= 4	Tolerance	Swift 2004
Berberis fremontii	Fremont Barberry	VT	<= 4	Tolerance	Swift 2004
Robinia neo-mexicana	New Mexican Locust	VT	<= 4	Tolerance	Swift 2004
Rosa woodsii	Wood's Rose	VT	<= 4	Tolerance	Swift 2004
Salix exigua	Coyote Willow	VT	<= 4	Tolerance	Swift 2004
Argemone species	Prickly Poppies	VT	2 - 4	Tolerance	Swift 2004
Calochorutus species	Mariposa Lilly	VT	2 - 4	Tolerance	Swift 2004
Chyrsopsis villosa	Hairy Goldenaster	VT	2 - 4	Tolerance	Swift 2004
Gallardia pennatifida	Cutleaf Blanketflower	VT	2 - 4	Tolerance	Swift 2004
Mentzelia species	Blazing Stars	VT	2 - 4	Tolerance	Swift 2004
Physaria australus	Twinpod	VT	2 - 4	Tolerance	Swift 2004
Acer negundo	Box-elder	VT	<= 6	Tolerance	Swift 2004
Acer ginnala	Amur maple	VT	<= 6	Tolerance	Swift 2004
Betula lenta	Sweet Birch	VT	<= 6	Tolerance	Swift 2004
Betula populifolia	Grey Birch	VT	<= 6	Tolerance	Swift 2004
Betula alleghaniensis	Yellow Birch	VT	<= 6	Tolerance	Swift 2004
Betula papyrifera	Paper Birch	VT	<= 6	Tolerance	Swift 2004
Fraxinus americana	White Ash	VT	<= 6	Tolerance	Swift 2004
Populus alba	White Poplar	VT	<= 6	Tolerance	Swift 2004
Populus deltoides	Eastern Cottonwood	VT	<= 6	Tolerance	Swift 2004
Populus grandidentata	Large-toothed Aspen	VT	<= 6	Tolerance	Swift 2004
Populus nigra	Lombardy Poplar	VT	<= 6	Tolerance	Swift 2004
Populus tremuloides	Trembling Aspen	VT	<= 6	Tolerance	Swift 2004
Prunus padus	European Bird Cherry	VT	<= 6	Tolerance	Swift 2004
Prunus serotina	Black Cherry	VT	<= 6	Tolerance	Swift 2004
Prunus virginiana	Choke Cherry	VT	<= 6	Tolerance	Swift 2004
Salix alba `Tristis'	Golden Weeping Willow	VT	<= 6	Tolerance	Swift 2004
Salix alba `Vitellina'	Golden Willow	VT	<= 6	Tolerance	Swift 2004
Salix nigra	Black Willow	VT	<= 6	Tolerance	Swift 2004
Sophora japonica	Japanese Pagoda Tree	VT	<= 6	Tolerance	Swift 2004
Ulmus pumila	Siberian Elm	VT	<= 6	Tolerance	Swift 2004
Pinus ponderosa	Ponderosa Pine	VT	<= 6	Tolerance	Swift 2004
Pinus thunbergiana	Japanese Black Pine	VT	<= 6	Tolerance	Swift 2004
Thuja occidentalis	American Arborvitae	VT	<= 6	Tolerance	Swift 2004

Table B3-1
Vegetation Soil Salinity Threshold and Tolerance Values Based on Chronic Studies

Receptor	Common Name	Classification[1]	Salinity (dS/m)	Endpoint[2]	Reference
Artemisia frigida	Fringed Sagewort	VT	<= 6	Tolerance	Swift 2004
Artemisia spinescens	Bud Sagebrush	VT	<= 6	Tolerance	Swift 2004
Artemisia tridentata	Basin Big Sagebrush	VT	<= 6	Tolerance	Swift 2004
Buxus microphylla	Japanese Boxwood	VT	<= 6	Tolerance	Swift 2004
Chrysothamnus nauseosus	Rubber Rabbitbrush	VT	<= 6	Tolerance	Swift 2004
Chrysothamnus visci diflorus	Douglas Rabbitbrush	VT	<= 6	Tolerance	Swift 2004
Ephedra nevadensis	Nevada Mormontea	VT	<= 6	Tolerance	Swift 2004
Forsythia x intermedia	Showy Border Forsythia	VT	<= 6	Tolerance	Swift 2004
Juniperus communis	Common Juniper	VT	<= 6	Tolerance	Swift 2004
Philadelphus coronarius	Sweet Mockorange	VT	<= 6	Tolerance	Swift 2004
Purshia glandulsa	Desert Bitterbrush	VT	<= 6	Tolerance	Swift 2004
Pyracantha fortuneana	Pyracantha	VT	<= 6	Tolerance	Swift 2004
Rhus glabra	Smooth Sumac	VT	<= 6	Tolerance	Swift 2004
Rhus trilobata	Three-leaf Sumac	VT	<= 6	Tolerance	Swift 2004
Shepherdia rotundifolia	Roundleaf Buffaloberry	VT	<= 6	Tolerance	Swift 2004
Spirea `Froebel's'	Froebel's spirea	VT	<= 6	Tolerance	Swift 2004
Fallugia paradoxa	Common Apache	VT	4 - 6	Tolerance	Swift 2004
Oenothera caespitosa	Tufted Evening Primrose	VT	4 - 6	Tolerance	Swift 2004
Sphaeralcea coccinea	Scarlet Globemallow	VT	4 - 6	Tolerance	Swift 2004
Yucca elata Soaptree	Yucca	VT	4 - 6	Tolerance	Swift 2004
Yucca glauca	Small Soapweed	VT	4 - 6	Tolerance	Swift 2004
Acer plantanoides	Norway Maple	VT	<= 8	Tolerance	Swift 2004
Aesculus hippocastanum	Common Horsechestnut	VT	<= 8	Tolerance	Swift 2004
Ailanthus altissima	Tree of Heaven	VT	<= 8	Tolerance	Swift 2004
Amelanchier canadensis	Shadblow	VT	<= 8	Tolerance	Swift 2004
Crataegus crus-galli	Cockspur Hawthorn	VT	<= 8	Tolerance	Swift 2004
Elaeagnus angustifolia	Russian Olive	VT	<= 8	Tolerance	Swift 2004
Gleditsia triacanthos	Honeylocust	VT	<= 8	Tolerance	Swift 2004
Quercus alba	White Oak	VT	<= 8	Tolerance	Swift 2004
Quercus robur	English Oak	VT	<= 8	Tolerance	Swift 2004
Quercus rubra	Red oak	VT	<= 8	Tolerance	Swift 2004
Robinia pseudoacacia	Black Locust	VT	<= 8	Tolerance	Swift 2004
Ptelea trifoliata	Wafer Ash	VT	<= 8	Tolerance	Swift 2004
Juniperus chinensis	Pfitzer juniper	VT	<= 8	Tolerance	Swift 2004
Picea glauca ` densata'	Black Hills Spruce	VT	<= 8	Tolerance	Swift 2004
Pinus mugo	Mugho Pine	VT	<= 8	Tolerance	Swift 2004
Pinus nigra	Austrian Pine	VT	<= 8	Tolerance	Swift 2004
Caragana arborescens	Siberian Peashrub	VT	<= 8	Tolerance	Swift 2004
Chrysothamnus albidus	Alkali Rabbitbrush	VT	<= 8	Tolerance	Swift 2004
Cytisus scoparius	Scotch Broom	VT	<= 8	Tolerance	Swift 2004
Elaeagnus commutata	Silverberry	VT	<= 8	Tolerance	Swift 2004
Elaeagnus multiflora	Cherry Elaeagnus	VT	<= 8	Tolerance	Swift 2004

Table B3-1
Vegetation Soil Salinity Threshold and Tolerance Values Based on Chronic Studies

Receptor	Common Name	Classification[1]	Salinity (dS/m)	Endpoint[2]	Reference
Euonymous japonica	Spindle Tree	VT	<= 8	Tolerance	Swift 2004
Halimodendron halodendron	Salt-tree	VT	<= 8	Tolerance	Swift 2004
Hippophae rhamnoides	Sea Buckthorn	VT	<= 8	Tolerance	Swift 2004
Juniperus chinensis	Pfitzer Juniper	VT	<= 8	Tolerance	Swift 2004
Lonicera tatarica	Tararian honeysuckel	VT	<= 8	Tolerance	Swift 2004
Rhamnus cathartica	Common Buckthorn	VT	<= 8	Tolerance	Swift 2004
Rhus trilobata	Squawbush	VT	<= 8	Tolerance	Swift 2004
Rhus typhina	Staghorn Sumac	VT	<= 8	Tolerance	Swift 2004
Rhamnus frangula	Glossy Buckthorn	VT	<= 8	Tolerance	Swift 2004
Shepherdia canadensia	Buffaloberry	VT	<= 8	Tolerance	Swift 2004
Spiraea vanhouttei	Van Houtte Spirea	VT	<= 8	Tolerance	Swift 2004
Symphoricarpuos albus	Snowberry	VT	<= 8	Tolerance	Swift 2004
Syringa amurensis japonica	Japanese Tree Lilac	VT	<= 8	Tolerance	Swift 2004
Syringa vulgaris	Common Lilac	VT	<= 8	Tolerance	Swift 2004
Potentilla fruiticosa `Jackmanii'	Jackman's potentilla	VT	<= 8	Tolerance	Swift 2004
Tamarix gallica	Manna Plant	VT	<= 8	Tolerance	Swift 2004
Agropyron cristatum	Crested Wheatgrass	VT	4 - 8	Tolerance	Swift 2004
Agropyron riparium	Streambank Wheatgrass	VT	4 - 8	Tolerance	Swift 2004
Agropyron trachycaulum	Slender Wheatgrass	VT	4 - 8	Tolerance	Swift 2004
Arrhenatherum elatium	Tall meadow oatgrass	VT	4 - 8	Tolerance	Swift 2004
Bromus inermis	Smooth brome	VT	4 - 8	Tolerance	Swift 2004
Buchloe dactyloides	Buffalograss	VT	4 - 8	Tolerance	Swift 2004
Dactylis glomerata	Orchardgrass	VT	4 - 8	Tolerance	Swift 2004
Elymus giganteus	Mammoth wildrye	VT	4 - 8	Tolerance	Swift 2004
Elymus junceus	Russian wildrye	VT	4 - 8	Tolerance	Swift 2004
Festuca arundinacea	Tall Fescue	VT	4 - 8	Tolerance	Swift 2004
Medicago sativa	Alfalfa	VT	4 - 8	Tolerance	Swift 2004
Phalaris arundinacea	Reed Canarygrass	VT	4 - 8	Tolerance	Swift 2004
Aquilegia micrantha	Cliff Columbine	VT	6 - 8	Tolerance	Swift 2004
Machaeranthera xylorrhiza	Common Woody Aster	VT	6 - 8	Tolerance	Swift 2004
Psilostrophe bakerii	Paperflower	VT	6 - 8	Tolerance	Swift 2004
Stanley pinnata	Prince's Plume	VT	6 - 8	Tolerance	Swift 2004
Atriplex canescens	Fourwing Saltbush	VT	<= 10	Tolerance	Swift 2004
Atriplex convertifolia	Shadscale Saltbush	VT	<= 10	Tolerance	Swift 2004
Atriplex corrugata	Mat Saltbush	VT	<= 10	Tolerance	Swift 2004
Atriplex nuttalli	Nuttall Saltbush	VT	<= 10	Tolerance	Swift 2004
Atriplex nuttalli cuneata	Castle Valey Clover	VT	<= 10	Tolerance	Swift 2004
Atriplex nuttalli gardneri	Gardner Saltbush	VT	<= 10	Tolerance	Swift 2004
Baccharis emoryi	Emory Baccharis	VT	<= 10	Tolerance	Swift 2004
Baccharis glutinosa	Seep-Willow	VT	<= 10	Tolerance	Swift 2004
Ceratoides lanata	Common Winterfat	VT	<= 10	Tolerance	Swift 2004
Chrysothamnus greenei	Greene Rabbitbrush	VT	<= 10	Tolerance	Swift 2004

Table B3-1
Vegetation Soil Salinity Threshold and Tolerance Values Based on Chronic Studies

Receptor	Common Name	Classification[1]	Salinity (dS/m)	Endpoint[2]	Reference
Chrysothamnus linifolius	Flaxleaf Rabbitbrush	VT	<= 10	Tolerance	Swift 2004
Ephedra species	Mormon Teas	VT	<= 10	Tolerance	Swift 2004
Ephedra torreyana	Torrey Ephedra	VT	<= 10	Tolerance	Swift 2004
Kochia americana	Greenmolly Summercypruss	VT	<= 10	Tolerance	Swift 2004
Sarcobatus vermiculatus	Black Greasewood	VT	<= 10	Tolerance	Swift 2004
Tamarix pentandra	Five-Stamen Tamarix, Tamarisk	VT	<= 10	Tolerance	Swift 2004
Bromus marginatus	Mountain brome	VT	8 - 12	Tolerance	Swift 2004
Lolium perenne	Perennial ryegrass	VT	8 - 12	Tolerance	Swift 2004
Melilotus alba	White sweet clover	VT	8 - 12	Tolerance	Swift 2004
Melilotus officinalis	Yellow sweet clover	VT	8 - 12	Tolerance	Swift 2004
Trifolium fragiferum	Strawberry clover	VT	8 - 12	Tolerance	Swift 2004
Agropyron elongatum	Tall Wheatgrass	VT	14 - 18	Tolerance	Swift 2004
Agropyron smithii	Western Wheatgrass	VT	14 - 18	Tolerance	Swift 2004
Distichlis	Saltgrass	VT	14 - 18	Tolerance	Swift 2004
Elymus triticoides	Beardless wildrye	VT	14 - 18	Tolerance	Swift 2004
Lotus corniculatus	Birdsfoot trefoil	VT	14 - 18	Tolerance	Swift 2004
Puccinellia	alkaligrass	VT	14 - 18	Tolerance	Swift 2004
Sporobolus airoides	Alkali sacaton	VT	14 - 18	Tolerance	Swift 2004

Footnotes
1 - VT = Vegetation - Terrestrial, Crop = Vegetation grown for market

3.2 Surface Water

Saline surface water can have several types of toxic or adverse impacts depending upon how it is used. Through the available literature, Waterstone was able to evaluate the impacts of saline surface water when used for irrigation and stock watering and for aquatic life.

3.2.1 Irrigation Water

The most important irrigation water quality factor influencing crop productivity in Colorado is conductivity. Water with an EC of only 1.15 dS/m contains 2000 pounds of salt for every acre-foot of water. Irrigation water with high EC values reduces the ability of the plants to compete with ions in the soil solution for water. The higher the EC, the less water is available to the plants, even though a field may appear wet. However, the permeability of the soil can influence the quality of irrigation water considered acceptable. As discussed previously, high permeability soils can leach salts out of the root zone. Thus, crops in high permeability soils can tolerate irrigation water with higher conductivities than crops grown in low permeability soils. Table B3-2 illustrates this concept. For example, plants that are moderately salt tolerant can utilize irrigation water with conductivities ranging from 2.5-5.9 dS/m in sandy soils, but can only utilize irrigation water with conductivities ranging from 0.84-1.98 in heavy clay soils.

The relationship between soil permeability and water conductivity would be especially important for CDOT facilities in alpine and subalpine environments. Many CDOT salt pile facilities are located in alpine and subalpine environments and these environments are characterized by highly permeable soils. Thus, runoff from salt piles in these environments may be expected to have significantly less impact on root zone soil salinity than the same quality runoff in a low soil permeability environment. Impacts to groundwater, however, may be greater in alpine and subalpine areas where high permeability soils overlay aquifers with fractured granite flow paths.

Salinity can also degrade the structure of soil as well as cause adverse impacts to vegetation. High concentrations of sodium relative to calcium and magnesium ions, calculated as the sodium

Table B3-2
Average Root Zone Salinity Compared to Irrigation Water Conductivity Thresholds for Various Soil Types

Plant Salt Tolerance	Water or Soil Salinity Rating	Average Root Zone Salinity,ECse (dS/m)	Irrigation Water ECi Threshold (dS/m) for Crops Growing in:			
			Sand	Loam	Light Clay	Heavy Clay
Sensitive	very low	<0.95	<1.25	<0.69	<0.69	<0.42
Moderately sensitive	low	=>0.95-1.9	=>1.25-2.51	=>0.69-1.38	=>0.69-1.38	=>0.42-0.84
Moderately tolerant	medium	>1.9-4.5	>2.51-5.94	>1.38-3.27	>1.38-3.27	>0.84-1.98
Tolerant	high	>4.5-7.7	>5.94-10.16	>3.27-5.85	>3.27-5.85	>1.98-3.39
Very tolerant	very high	>7.7-12.2	>10.16-16.10	>5.85-8.86	>5.85-8.86	>3.39-5.37
No plants	extreme	>12.2	>16.10	>8.86	>8.86	>5.37

ECse = Average root zone salinity (dS/m)
ECi = Electrical conductivity of irrigation water (dS/m)
LF = leaching factor
ECse = ECi/(2.2)LF

Soil Type	Average Root Zone LF
Sand	0.6
Loam	0.33
Light Clay	0.33
Heavy Clay	0.2

absorption ratio (SAR), in irrigation water can degrade well structured soils causing a reduction in both aeration and soil permeability to water. Calculating the SAR for surface water is not possible without a water analysis that includes the concentrations of the three ions. Therefore, this topic is more appropriately considered during a later site investigation phase with surface water analyses.

3.2.2 Stock Water

Table B3-3 provides limited, easily available data on chronic sodium chloride toxicity values for stock watering. In general, this table illustrates that avian species are more sensitive than mammals and that cattle and sheep can likely tolerate conductivity values up to at least 8000 mg/L of NaCl (approximately 10 dS/m) with little or no effect. The most important finding, however, is that, in general, livestock can tolerate significantly higher water salinities than plants. As Table B3-2 illustrates, even very tolerant plant species can only tolerate irrigation water with ECs of approximately 5 dS/m in low permeability soils. Therefore, it is likely that significant impacts to plants would occur before stock water salinity would be a problem.

Table B3-4 illustrates current recommendations from the Food and Agriculture Organization of the United Nations for water quality for livestock and poultry (Ayers and Westcot 1994). These recommendations are consistent with the livestock data summarized in Table B3-3.

3.2.3 Aquatic Life

Aquatic plant and animal species vary quite widely in their ability to tolerate salinity in general and chloride ions specifically. USEPA’s chronic AWQC for aquatic life is based on chloride and has a value of 230 mg/L. Typical streams in Colorado have 4 mg/L of chloride (Lewis 1997). AWQC values are developed to protect a wide variety of aquatic life. Table B3-5 lists sodium chloride chronic toxicity values, primarily lowest observed effect or no observed effect values, for a wide range of aquatic species. Equivalent values could not be located for magnesium chloride.

Table B3-3
Livestock Health Effects Related to Stock Water Conductivity Values

Common Name	Classification	Route of Exposure	Duration[1]	NaCl (mg/L)	Conductivity (dS/m)	Health Effects	Reference
Chicken (1 d old)	Livestock	Water	28 d	4000	5.00	Anorexia	Mineral Tolerance of Domestic Animals, 1980
Chicken (1 d old)	Livestock	Water	112d	4000	5.00	No effect	Mineral Tolerance of Domestic Animals, 1980
Turkey (1 d old)	Livestock	Water	28 d	4000	5.00	Anorexia, decreased weight gain, increased mortality	Mineral Tolerance of Domestic Animals, 1980
Duck (1 d old)	Livestock	Water	21 d	4000	5.00	No effect	Mineral Tolerance of Domestic Animals, 1980
Sheep	Livestock	Water	21 d	5000	6.25	No effect	Mineral Tolerance of Domestic Animals, 1980
Chicken (1 d old)	Livestock	Water	28 d	7000	8.75	Anorexia, decreased weight gain, increased mortality	Mineral Tolerance of Domestic Animals, 1980
Cattle	Livestock	Water	30 d	10000	12.50	No effect	Mineral Tolerance of Domestic Animals, 1980
Cattle	Livestock	Water	30 d	10000	12.50	Increased water consumption	Mineral Tolerance of Domestic Animals, 1980
Sheep	Livestock	Water	21 d	10000	12.50	No effect	Mineral Tolerance of Domestic Animals, 1980
Sheep	Livestock	Water	460 d	10000	12.50	No effect	Mineral Tolerance of Domestic Animals, 1980
Chicken (1 d old)	Livestock	Water	28 d	10000	12.50	Anorexia, decreased weight gain, nervousness, edema and mortality	Mineral Tolerance of Domestic Animals, 1980
Cattle	Livestock	Water	30 d	12000	15.00	Increased water consumption	Mineral Tolerance of Domestic Animals, 1980
Chicken (1 d old)	Livestock	Water	28 d	12000	15.00	Anorexia, decreased weight gain, nervousness, edema and mortality	Mineral Tolerance of Domestic Animals, 1980
Cattle	Livestock	Water	30 d	12500	15.63	Reduced growth rate	Mineral Tolerance of Domestic Animals, 1980
Cattle	Livestock	Water	30 d	15000	18.75	Reduced growth rate, reduced water intake	Mineral Tolerance of Domestic Animals, 1980
Sheep	Livestock	Water	21 d	15000	18.75	Decreased feed intake	Mineral Tolerance of Domestic Animals, 1980
Sheep	Livestock	Water	460 d	15000	18.75	Decreased feed consumption and body weight	Mineral Tolerance of Domestic Animals, 1980
Cattle	Livestock	Water	30 d	17500	21.88	Weight loss; anorexia; reduced water intake	Mineral Tolerance of Domestic Animals, 1980
Cattle	Livestock	Water	30 d	20000	25.00	Anorexia; weight loss, lethargy, anhydremia, collapse	Mineral Tolerance of Domestic Animals, 1980
Sheep	Livestock	Water	21 d	20000	25.00	Decreased feed intake	Mineral Tolerance of Domestic Animals, 1980
Sheep	Livestock	Water	460 d	20000	25.00	Decreased feed consumption and body weight, weakness	Mineral Tolerance of Domestic Animals, 1980

Footnotes
1 = length of study in day(s)

Table B3-4
Water Quality Guide for Livestock and Poultry Uses

Water Salinity, EC (dS/m) (mg/L)	Rating	Remarks
<1.5 (<1,200 mg/L)	Excellent	Usable for all classes of livestock and poultry.
=>1.5 - 5.0 (=>1,200 - 4,000 mg/L)	Very Satisfactory	Usable for all classes of livestock and poultry. May cause temporary diarrhea in livestock not accustomed to such water; watery droppings in poultry.
>5.0 - 8.0 (>4,000 - 6,400 mg/L)	Satisfactroy for Livestock	May cause temporary diarrhea or be refused at first by animals not accustomed to such water.
	Unfit for Poultry	Often causes watery feces, increased mortality and decreased growth, especially in turkey.
>8.0 - 11.0 (>6,400 - 8,800 mg/L)	Limited Use for Livestock	Usable with reasonable safety for dairy and beef cattle, sheep, swine and horses. Avoid use for pregnant or lactating animals.
	Unfit for Poultry	Not acceptable for poultry.
>11.0 - 16.0 (>8,800 - 12,800 mg/L)	Very Limited Use	Unfit for poultry and probably unfit for swine. Considerable risk in using for pregnant or lactating cows, horses, sheep, or for the use of the young of these species. In general, use should be avoided although older ruminants, horses, poultry and swine may subsist on waters such as these under certain conditions.
>16.0 (>12,800 mg/L)	Not Recommended	Risks with such highly saline water are so great that it cannot be recommended for use under any conditions.

Source: Ayers and Wescot 1994
Salinity values (mg/L) in parentheses are added and approximated on the basis of 1 dS/m = 800 mg/L of NaCl.

Table B3-5
Health Effects of Sodium Chloride Concentration Level for Aquatic Species Based on Chronic Studies

Receptor	Common Name	Classification	Study Method[1]	Duration[2]	NaCl (mg/L)	Conductivity (dS/m)	Endpoint[3]	Reference
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	2.00	0.00	NOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	2.70	0.00	LOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	2.70	0.00	NOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	2.70	0.00	NOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	3.50	0.01	LOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	3.50	0.01	LOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	4.00	0.01	NOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	7 d	4.00	0.01	NOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	7 d	4.00	0.01	NOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	4.00	0.01	NOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	5.60	0.01	NOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	6.00	0.01	LOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	7 d	6.00	0.01	LOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	7 d	7.00	0.01	LOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	7.00	0.01	LOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	7.00	0.01	LOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	7.00	0.01	LOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	7.00	0.01	LOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	7.00	0.01	NOEC	Diamond, J.M., et al., 1992
Stenonema modestum	Mayfly	Aquatic Invertebrate	R	14 d	7.00	0.01	NOEC	Diamond, J.M., et al., 1992
Spirogyra setiformis	Alga	Aquatic Invertebrate	Water	10 d	71.00	0.11	Inhibition:growth, chlorophyll, C14 fixation	Shitole and Joshi 1984
Netrium digitus	Desmid	Aquatic Invertebrate	Water	21 d	200.00	0.31	Growth inhibition	Hosiaisluoma 1976
Netrium digitus	Desmid	Aquatic Invertebrate	Water	21 d	250.00	0.39	Growth inhibition	Hosiaisluoma 1976
Daphnia pulex	Water flea	Aquatic Invertebrate	R	21 d	314.00	0.49	NOEC	Birge, W.J., et al., 1985
Daphnia pulex	Water flea	Aquatic Invertebrate	R	21 d	314.00	0.49	NOEC	Birge, W.J., et al., 1985
Daphnia pulex	Water flea	Aquatic Invertebrate	R	21 d	314.00	0.49	NOEC	Birge, W.J., et al., 1985
Paramecium tetrourelia	Protozoon	Aquatic Invertebrate	Water	5 d	350.00	0.55	17% reduction in cell division	Cronkite et al. 1985
Daphnia pulex	Water flea	Aquatic Invertebrate	R	21 d	372.00	0.58	MATC	Birge, W.J., et al., 1985
Daphnia pulex	Water flea	Aquatic Invertebrate	R	21 d	372.00	0.58	MATC	Birge, W.J., et al., 1985
Daphnia pulex	Water flea	Aquatic Invertebrate	R	21 d	372.00	0.58	MATC	Birge, W.J., et al., 1985
Rana Breviceps	frog	Aquatic Invertebrate		Chronic	400.00	0.63	NOEC	USEPA 1988
Daphnia pulex	Water flea	Aquatic Invertebrate	R	21 d	441.00	0.69	LOEC	Birge, W.J., et al., 1985
Daphnia pulex	Water flea	Aquatic Invertebrate	R	21 d	441.00	0.69	LOEC	Birge, W.J., et al., 1985
Daphnia pulex	Water flea	Aquatic Invertebrate	R	21 d	441.00	0.69	LOEC	Birge, W.J., et al., 1985
Oncorhynchus mykiss	Rainbow trout,donaldson trout	Fish	F	90 d	643.00	1.00	NOEC	Spehar, R.L., 1987
Pithophora oedogonia	Alga	Aquatic Vegetation	Water	10 d	886.00	1.38	Inhibition:growth, chlorophyll, C14 fixation	Shitole and Joshi 1984
Oncorhynchus mykiss	Rainbow trout,donaldson trout	Fish	F	90 d	923.00	1.44	MATC	Spehar, R.L., 1987
Oncorhynchus mykiss	Rainbow trout,donaldson trout	Fish	F	56 d	955.00	1.49	NOEC	Spehar, R.L., 1986
Daphnia magna	Cladoceran	Aquatic Invertebrate	Water	21 d	1062.00	1.66	64 h	Biesinger and Christensen 1972
Oncorhynchus mykiss	Rainbow trout,donaldson trout	Fish	F	90 d	1324.00	2.07	LOEC	Spehar, R.L., 1987
Oncorhynchus mykiss	Rainbow trout,donaldson trout	Fish	F	56 d	1324.00	2.07	NOEC	Spehar, R.L., 1987
Oncorhynchus mykiss	Rainbow trout,donaldson trout	Fish	F	56 d	1356.00	2.12	MATC	Spehar, R.L., 1986
Ceriodaphnia dubia	Water flea	Aquatic Invertebrate	R	7 d	1500.00	2.34	NOEC	DeGraeve, G.M., et al., 1992
Notropis sp.	Shiners	Fish	Water	5 d	1525.00	2.38	Reduced Survival	Van Horn et al. 1949
Potamogetan pectinatus	Angiosperm (seed)	Aquatic Vegetation	Water	28 d	1820.00	2.84	Reduced germination	Teeter 1965
Potamogetan pectinatus	Angiosperm (9 wks old)	Aquatic Vegetation	Water	35 d	1820.00	2.84	Reduced dry weight	Teeter 1965
Potamogetan pectinatus	Angiosperm (13 wks old)	Aquatic Vegetation	Water	35 d	1820.00	2.84	Reduced shoots and dry weight	Teeter 1965
Oncorhynchus mykiss	Rainbow trout,donaldson trout	Fish	F	56 d	1924.00	3.01	LOEC	Spehar, R.L., 1986
Oncorhynchus mykiss	Rainbow trout,donaldson trout	Fish	F	56 d	2740.00	4.28	LOEC	Spehar, R.L., 1987
Chlamydomonas reinhardtii	Alga	Aquatic Vegetation	Water	3-6 d	3014.00	4.71	Growth inhibition	Reynoso et al. 1982
Cyclops vernalis	Cyclopoid	Aquatic Invertebrate	S	96 h	3030.00	4.73	MATC	Anderson, et al., 1948
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996

Table B3-5
Health Effects of Sodium Chloride Concentration Level for Aquatic Species Based on Chronic Studies

Receptor	Common Name	Classification	Study Method[1]	Duration[2]	NaCl (mg/L)	Conductivity (dS/m)	Endpoint[3]	Reference
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	4000.00	5.00	NOEC	Pickering, Q.H., et al., 1996
Myriophyllum spicatum	Eurasian watermilfoil	Aquatic Vegetation	Water	32 d	3617.00	5.65	50 % reduction in dry weight	Stanley 1974
Daphnia magna	Water flea	Aquatic Invertebrate	S	96 h	4600.00	5.75	MATC	Anderson, et al., 1948
Daphnia magna	Water flea	Aquatic Invertebrate	S	96 h	3700.00	5.78	MATC	Anderson, et al., 1948
Leptodora kindtii	Water flea	Aquatic Invertebrate	S	96 h	3700.00	5.78	MATC	Anderson, et al., 1948
Myriophyllum spicatum	Eurasian watermilfoil	Aquatic Vegetation	Water	32 d	4964.00	6.21	50 % reduction in dry weight	Stanley 1974
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	5700.00	7.13	MATC	Pickering, Q.H., et al., 1996
Cyclops vernalis	Cyclopoid	Aquatic Invertebrate	S	96 h	6100.00	7.63	MATC	Anderson, et al., 1948
Chlorella emersonii	Alga	Aquatic Vegetation	Water	8-14 d	7000.00	8.75	Growth inhibition	Setter et al. 1982
Pimephales promelas	Fathead minnow	Fish	R	7 d	8000.00	10.00	LOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	8000.00	10.00	LOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	8000.00	10.00	LOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	8000.00	10.00	LOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	8000.00	10.00	LOEC	Pickering, Q.H., et al., 1996
Pimephales promelas	Fathead minnow	Fish	R	7 d	8000.00	10.00	LOEC	Pickering, Q.H., et al., 1996
Chlorella minitissimo	Alga	Aquatic Vegetation	Water	28 d	12100.00	15.13	Growth inhibition	Kessler 1974
Chlorella zofingiensis	Alga	Aquatic Vegetation	Water	28 d	12100.00	15.13	Growth inhibition	Kessler 1974
Anoboena variabilis	Alga	Aquatic Vegetation	Water	4 d	14000.00	17.50	Growth inhibition	Schiewer 1974
Chlorella fusca fusca	Alga	Aquatic Vegetation	Water	28 d	18200.00	22.75	Growth inhibition	Kessler 1974
Chlorella kessleri	Alga	Aquatic Vegetation	Water	28 d	18200.00	22.75	Growth inhibition	Kessler 1974
Chlorella vulgaris tertia	Alga	Aquatic Vegetation	Water	28 d	18200.00	22.75	Growth inhibition	Kessler 1974
Chlorella vulgaris	Alga	Aquatic Vegetation	Water	90-120	24100.00	30.13	Growth inhibition	De Jong 1965
Chlorella fusca rubescens	Alga	Aquatic Vegetation	Water	28 d	24300.00	30.38	Growth inhibition	Kessler 1974
Chlorella fusca vacuolata	Alga	Aquatic Vegetation	Water	28 d	24300.00	30.38	Growth inhibition	Kessler 1974
Chlorella vulgaris vulgaris	Alga	Aquatic Vegetation	Water	28 d	24300.00	30.38	Growth inhibition	Kessler 1974
Anacystis nidulans	Alga	Aquatic Vegetation	Water	4 d	>24300	30.38	Growth inhibition	Schiewer 1974
Chlorella protothecoides	Alga	Aquatic Vegetation	Water	28 d	30300.00	37.88	Growth inhibition	Kessler 1974
Chlorella saccharophilia	Alga	Aquatic Vegetation	Water	28 d	30300.00	37.88	Growth inhibition	Kessler 1974
Chorella luteoviridis	Alga	Aquatic Vegetation	Water	28 d	36400.00	45.50	Growth inhibition	Kessler 1974

Footnotes

[1]Study Method:
F = Flow-through water system
NR = Not Reported
R = Renewal (water in static containers, renewed periodically)
S = Static (water in static containers, not renewed)
Water = Route of exposure was drinking water

[2]Duration of Study:
d = day(s)
h = hour(s)
Chronic = >4 days

[3]Endpoint of Study
LOEC = Lowest Observable Effect Concentration
MATC = Maximum Acceptable Toxicant Concentration
NOEC = No Observable Effect Concentration
Growth inhibition = Concentration at which growth inhibition observed

Overall, this table illustrates that some aquatic insects, such as the mayfly, may be the most sensitive species while fathead minnows (a commonly used species for toxicity testing) and alga are highly tolerant of sodium chloride. Table B3-5 also lists the electrical conductivity value equivalent to the sodium chloride concentration. However, it is not possible to relate these conductivity values directly to acceptable irrigation water conductivities because the sodium chloride conductivity values would represent only a portion of the overall conductivity of surface or irrigation water.

3.3 Groundwater

The endpoints considered for groundwater include potential use as a drinking water source, as irrigation water and as stock water. Irrigation and stock water quality needs are discussed in Sections 3.2.1 and 3.2.2.

Studies on the toxicity of salt to humans have focused primarily on overall dietary salt intake. Estimates of typical daily salt intake for Americans range from 6000-9000 mg/day, with the primary source being processed foods (COMA 1994). Drinking water typically contributes very little to overall salt intake because municipal water treatment facilities remove most of the total dissolved solids (TDS). Taste thresholds and acceptability for sodium chloride concentrations in drinking water range up to 500 mg/L (Zoeteman, BCJ 1978). The USGS definition of freshwater is water with a TDS concentration < 1000 mg/L. For human health risk assessment purposes, a water consumption rate of 2L/day is assumed. Thus, for drinking water containing 500 mg/L of sodium chloride, a sodium chloride intake of 1000 mg/day from water could be assumed.

An adult acute toxicity value for salt has been identified as an intake of > 35,000 mg (35g) in one day (National Academy of Sciences, 1980). Symptoms include vomiting, ulceration of the gastrointestinal tract, muscle weakness and renal damage, leading to dehydration, metabolic acidosis and severe peripheral and central neural effects. If this intake is a one-time event, it can be treated and full recovery is possible.

No specific adult chronic toxicity value for salt has been identified. The primary adverse effect of increased sodium chloride in the diet is increased blood pressure, which is a major risk factor for cardiovascular-renal diseases. There is, however, a well-recognized heterogeneity in blood pressure response from different population groups. The most sensitive groups are older persons, African Americans, and individuals with hypertension, diabetes or chronic kidney disease. These groups are affected at intakes that would not cause an effect in the rest of the population. The Institute of Medicine of the National Academies (2004) has recently set a recommended upper limit (UL) of 5800 mg/day of sodium chloride, although they recognized that prolonged exercise in a hot environment could actually result in an increased need for sodium chloride above this level due to sweat losses.

CDOT will incorporate information on the adverse effects on dietary salt into the overall risk-based approach to groundwater. This approach will include multiple aspects:

- How much salt might be in the water (estimate)?
- For what purpose is the groundwater being used (irrigation, stock watering, domestic use, drinking)?
- How much salt is actually in the water (well testing)?
- For groundwater that may be used as drinking water at a consumption rate of 2L/day, what percentage of dietary salt would be attributable to groundwater?
- Could adverse impacts be related to the actual use of groundwater (e.g., at a consumption rate of 2L/day, how much salt would the groundwater contribute to the overall salt intake rate in a typical diet)?

A guideline of 500 mg/L of sodium chloride in groundwater is proposed. This guideline would be used within the overall salt pile facilities evaluation as follows:

1. Salt Pile Facility Ranking Process Step One (see Attachment A) used to prioritize sites based on semi-quantitative estimate of vulnerability of media (soil, surface water, groundwater) to impacts from salt pile facilities. Specific potential concentrations of sodium chloride in groundwater would not be estimated.

2. Salt Pile Facility Ranking Process Step Two (see Attachment A) used to prioritize sites based on estimated vulnerability of receptors to media (soil, surface water, groundwater) potentially impacted from salt pile facilities. This step includes site-specific field observations related to potential receptors as noted in the Step Two Questions. Actual or potential groundwater receptors identified, but no groundwater testing.

3. Salt pile facilities with high potential receptor vulnerability scores undergo site-specific investigations to measure actual impacts in terms of soil and surface water conductivity. Sodium chloride concentrations in groundwater would be measured. Groundwater with a sodium chloride concentration > 500 mg/L attributable to a salt pile facility, and currently or likely to be used as a drinking water source, would be prioritized for source remediation and potentially for remediation at the point of use, depending on site-specific circumstances

It should be noted that currently, 96% of extracted groundwater in Colorado is used for agriculture (Colorado Foundation for Water Education 2004). Domestic use of groundwater only occurs in a few small rural communities or private wells. Thus, CDOT's approach to groundwater could be similar to the Colorado Department of Agriculture's agricultural chemicals program, i.e., voluntary best management practices (BMPs) to minimize risk to groundwater (Colorado Foundation for Water Education 2004). At CDOT salt pile facilities where use of groundwater is a potential concern, BMPs would be combined with site-specific risk assessment.

4.0 COLORADO PHYSIOGRAPHIC REGION MAP

In order to determine whether it is possible to develop regional toxicity values in Colorado, Waterstone located as much physiographic, geologic, hydrologic, climactic, and biologic data for the state of Colorado as possible, with an emphasis on mapped data, to develop five regional divisions for the state. The following two sections present the physiographic basis for the proposed regions (4.1) and some of the dominant plant species and land uses in each region (4.2).

4.1 Basis for Proposed Physiographic Regions

State maps were created using existing GIS coverages where possible. GIS maps were created for average annual precipitation, geology, soil classification, water bodies and waterways, topography, vegetative land use and land cover, and hydrologic boundaries. The use of GIS allowed the simultaneous examination of all the maps, so that multiple characteristics in a single region or area could be readily identified. The most critical elements to consider with regard to the risk posed by salt pile storage were determined to be (1) precipitation, (2) vegetative land cover, and (3) geology/soil type. These elements were chosen because:

1) Average annual precipitation directly determines the quantity of water available to mobilize salts from storage facilities and transport them to potential sensitive receptors.

2) Vegetation will be the most frequently and directly impacted receptor for salts that have moved into soil and surface water. The dominant regional vegetation type(s) determine the amount of salinity in soil and surface water that can be tolerated.

3) Geology and soil type have a direct effect upon the pathways that are accessible for salt transport. Emphasis was placed upon the presence of bedrock and the relative permeability of the soil. Soils with a permeability of less than 0.6 inches per hour were classified as low permeability. Soil permeabilities of 0.6-2 inches per hour were considered low to moderate and soils with permeabilities of 2-6 inches per hour were classified as moderate to high permeability. Soils with permeabilites greater than 6 inches are considered high permeability. Salt storage facilities in areas with low permeability soils or with bedrock outcrops allow salt saturated precipitation to runoff into nearby surface water bodies. Areas with high permeability soils provide a preferential path to groundwater and soil. Some soil types have also been shown to have high background salinity and, therefore, would support vegetation that tolerates higher salinity values.

Regional divisions were created after careful examination of all of the gathered data. Table B4-1 summarizes the major features by region. Following is a brief description of each region.

Table B4-1
Summary of Major Regional Features
CDOT Salt Pile Risk Assessment Program Development

	Region 1	Region 2	Region 3	Region 4	Region 5
Precipitation	Less than 20 inches per year throughout the region.	13 to 63 inches per year.	Generaly less than 20 inches per year.	Generally less than 20 inches per year.	Less than 9 inches per year throughout the region.
Major Vegetation Type	Primarily grassland significant agricultural use.	Primarily conifers and high altitude deciduous trees, some isolated valleys with grassland and shrubland, limited agricultural use.	Mostly grasslands with some shrubland and chaparral, some agricultural use.	Mostly shrub land and chaparral with some agricultural use and occasional grasslands.	Primarily grasslands with a large component of agricultural use.
Geologic Features	Primarily un-lithified alluvial material.	Steeply sloping mountainsides dominated by hardrock outcrops, alluvial material in valleys.	Mostly un-lithified alluvium with areas of bedrock outcropps.	Mostly un-lithified alluvium with a significant component of bedrock outcrops.	Moslty un-lithified alluvial material.
Soil Permeability	~70% of Soils have permeability rates below 2 inches per hour.	~60% of soils in the region have permeability rates of less than 2 inches per hour.	~ 65% of the soils in the region have permeabilty rates in excess of 2 inches per hour.	~95% soils with permeability rates of less than 2 inches per hour.	~90% of soils have permeability rates in excess of 2 inches per hour.

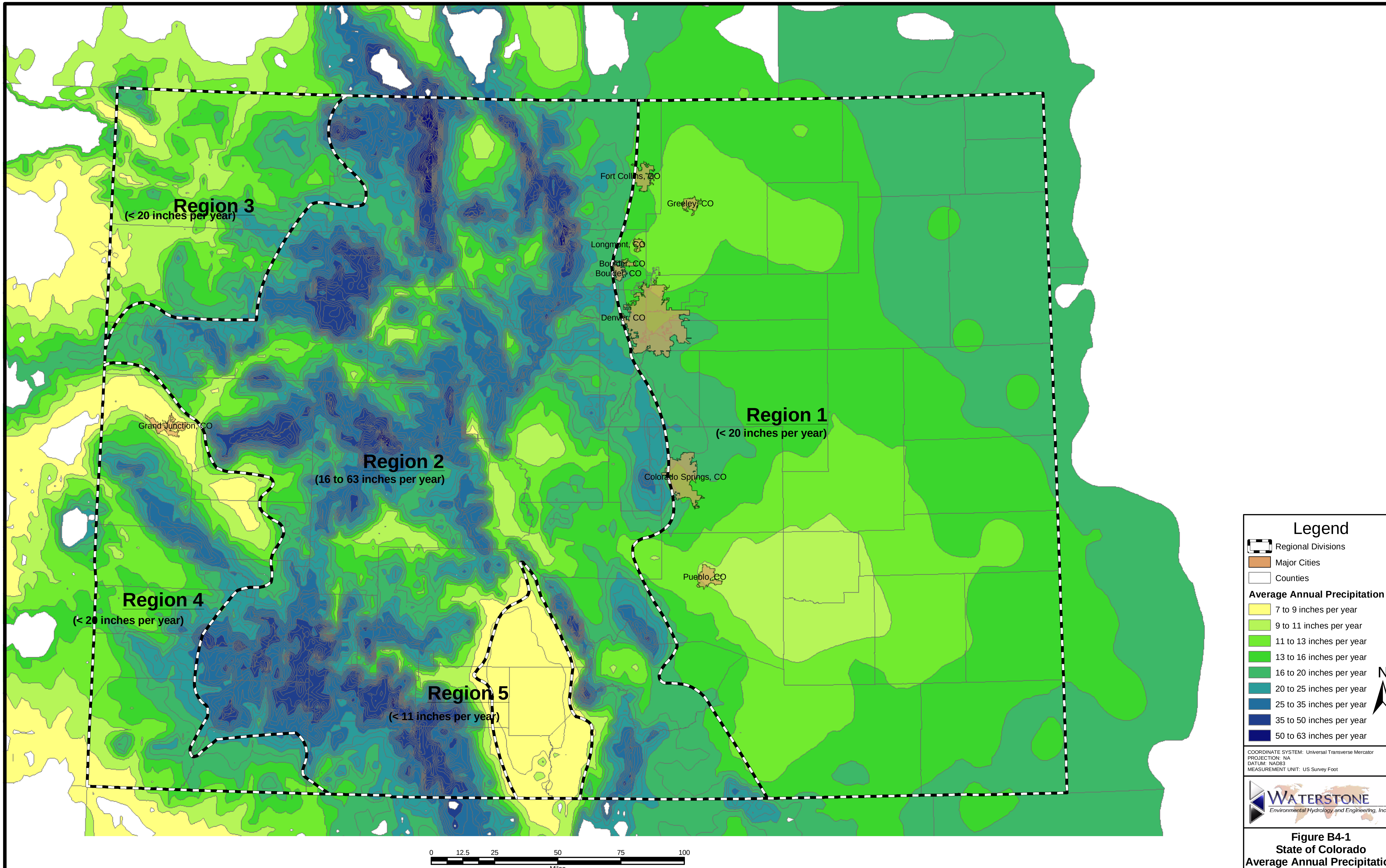


Figure B4-1
State of Colorado
Average Annual Precipitation
by Region

Average Annual Precipitation Data from:
The USDA/NRCS - National Cartography &
Geospatial Service Center

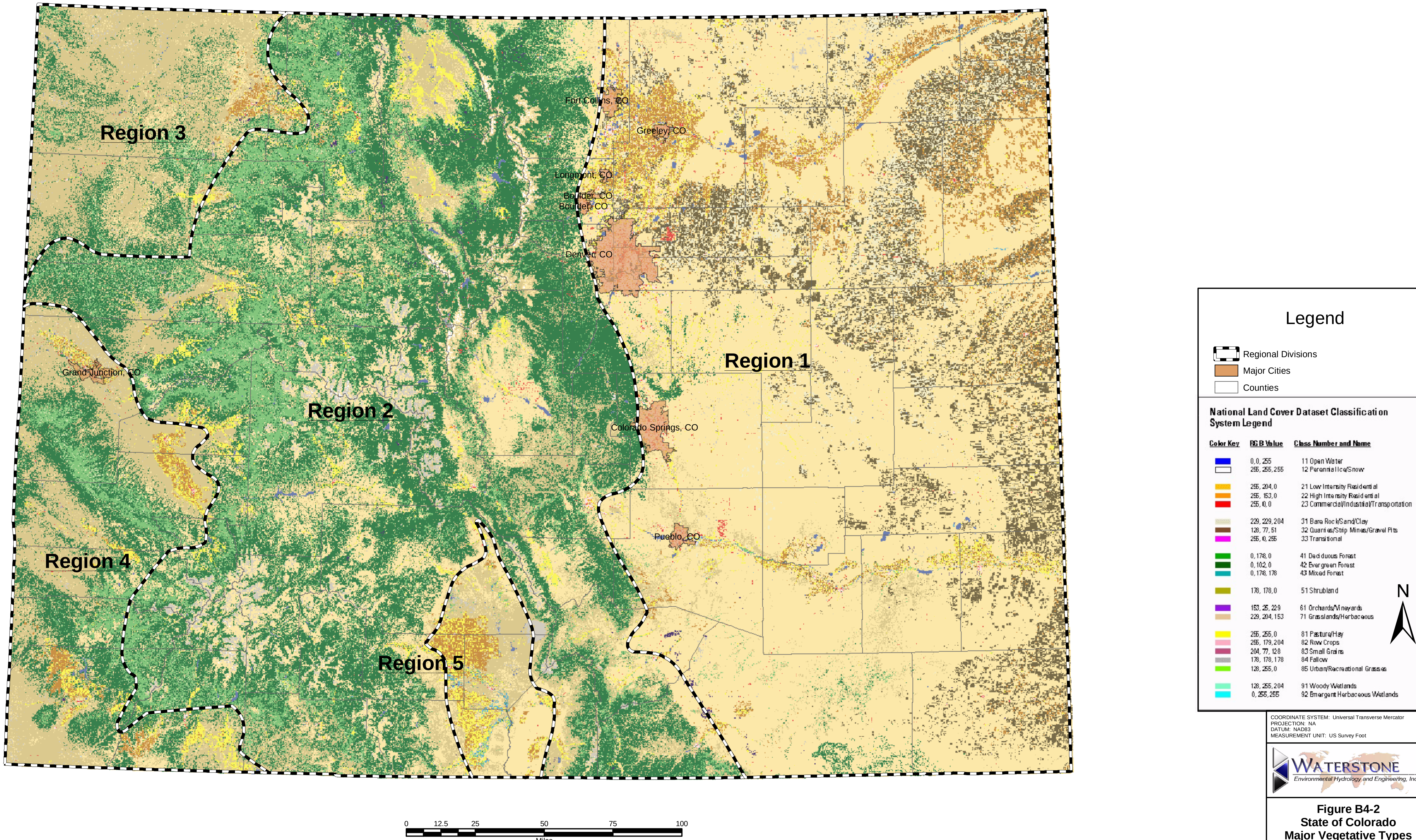


Figure B4-2
State of Colorado
Major Vegetative Types
by Region

Land Use Land Cover Information from:
The USDA/NRCS - National Cartography & Geospatial Service Center

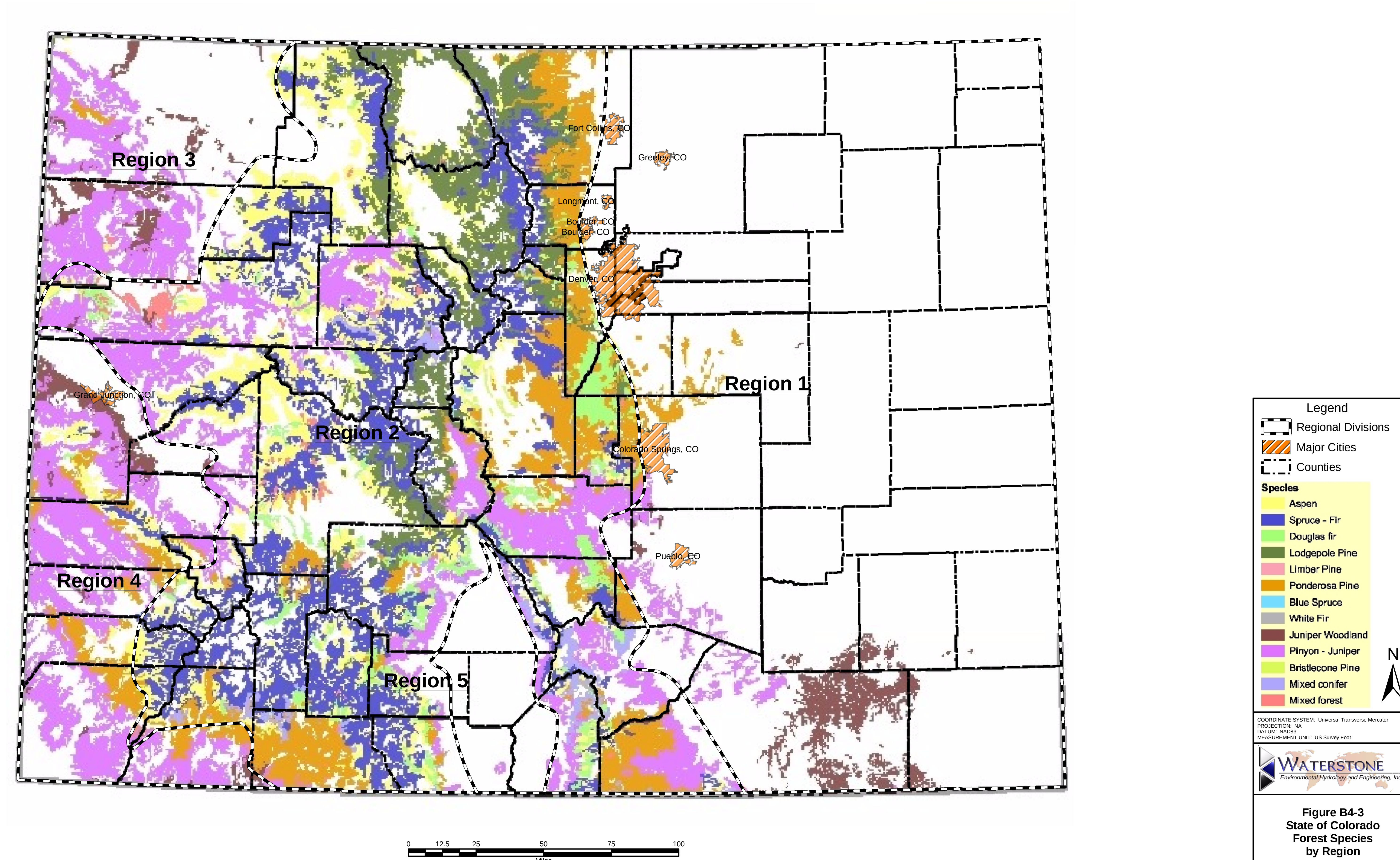


Figure B4-3
State of Colorado
Forest Species
by Region

Forest Species Map from:
Unknown Internet Source

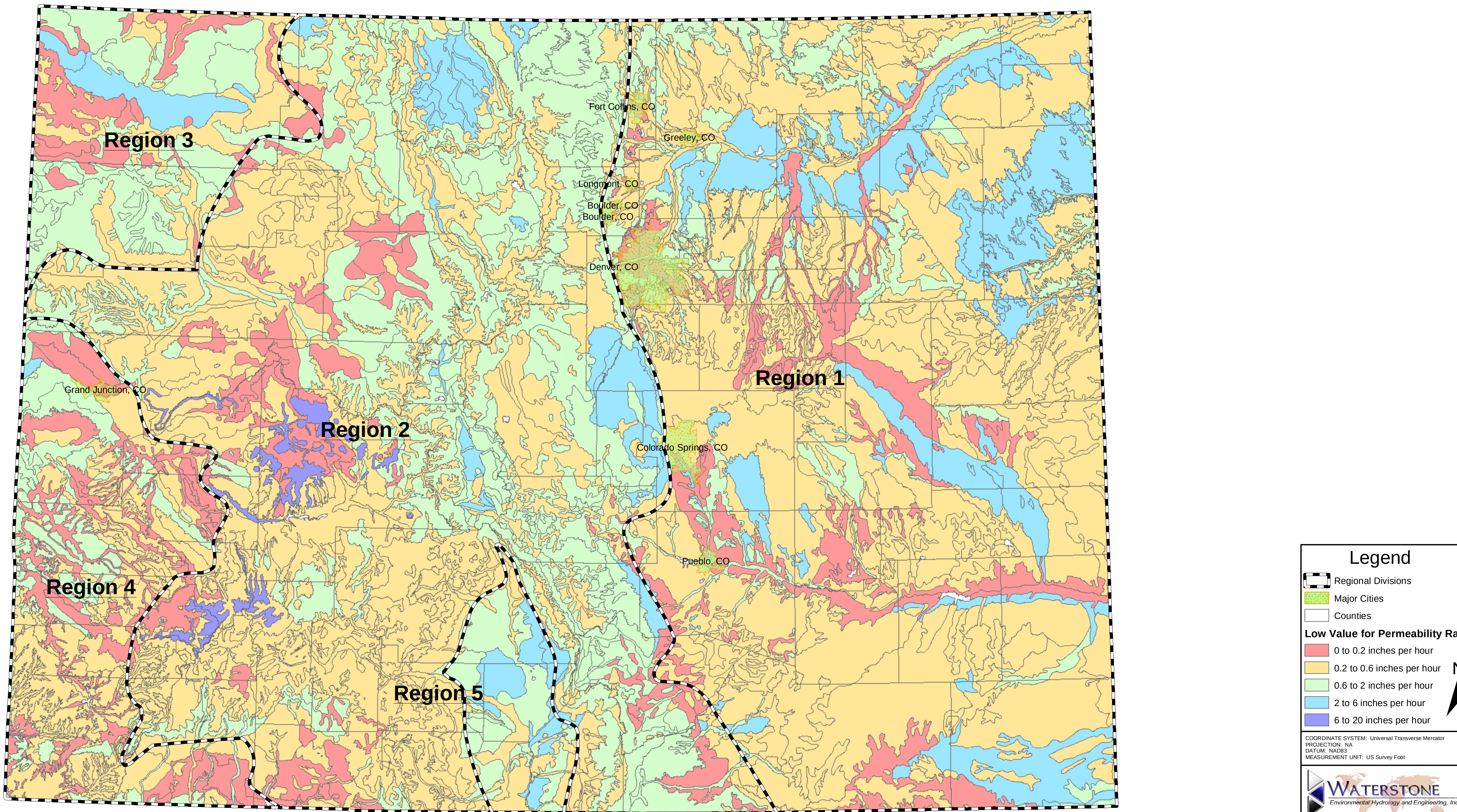
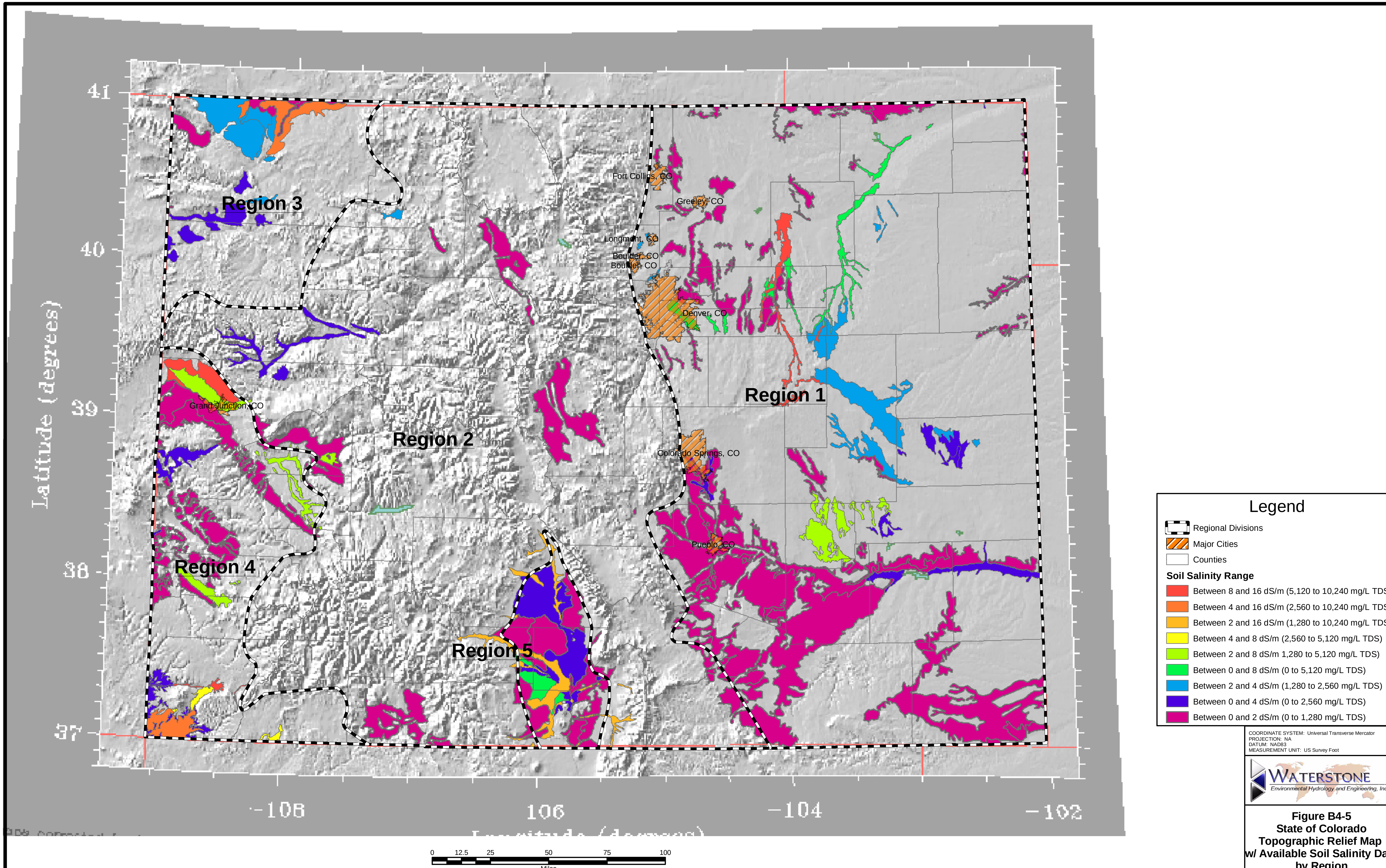


Figure B4-4
State of Colorado
Permeability Rate
Values for Soil by Region

STATSGO Soils Map from:
USDA, Soil Conservation Service
State Soil Geographic Data Base for Colorado



COORDINATE SYSTEM: Universal Transverse Mercator
PROJECTION: NA
DATUM: NAD83
MEASUREMENT UNIT: US Survey Foot

WATERSTONE
Environmental Hydrology and Engineering, Inc.

Figure B4-5
State of Colorado
Topographic Relief Map
w/ Available Soil Salinity Data
by Region

Soil Salinity Map from:
State Soil Geographic Data Base for Colorado
Black and White Relief Map from:
Johns Hopkins University Applied Physics Laboratory

- **Physiographic Region 1**

Physiographic Region 1 includes all of Eastern Colorado from the Front Range to the eastern border. Physiographic Region 1 receives less than twenty inches of precipitation per year. The region is covered primarily by grassland with significant agricultural use. Approximately 70% of the soils in the region are relatively low permeability. The near surface geology is primarily un-lithified alluvium. There is very little documented high background soil salinity.

- **Physiographic Region 2**

Physiographic Region 2 covers the entire Rocky Mountain area within Colorado, excluding the San Luis Valley. Physiographic Region 2 generally receives between 13 and 63 inches of precipitation per year, which is the bulk of the precipitation for the state. The vegetation in this region is primarily coniferous trees and high altitude deciduous trees. Approximately 60% of the soils in the region are relatively low permeability. There is a great deal of steeply sloped terrain dominated by bedrock outcrops. Virtually no background soil salinity data was available for this region.

- **Physiographic Region 3**

Physiographic Region 3 covers the northwestern corner of the state including most of Moffat and Rio Blanco counties, and the Steamboat Springs area of Routt County. This region generally receives less than 20 inches of precipitation per year. The vegetation in the region is mostly grassland with some areas of shrubland and chaparral. The region is approximately 65% high permeability soils. The near surface geology is mostly un-lithified alluvium, with occasional bedrock outcrops. No background soil salinity data was available for most of the region; however, there is an area of high background soil salinity in the northern portion of the region.

- **Physiographic Region 4**

Physiographic Region 4 covers the southwestern corner of the state from the Grand Valley to east of the Four Corners area. The region generally receives less than 20 inches of precipitation per year. The vegetation in the region is mostly shrub land and chaparral with some agricultural use and occasional grasslands. The region is approximately 95% low permeability soils. The near surface geology is mostly un-lithified alluvium with a significant component of bedrock outcrops. No background soil salinity data was available for the majority of the region, however there is a significant area of high background soil salinity in the Grand Valley, and another in southwest corner of the state adjacent to the Four Corners area.

· **Physiographic Region 5**

Physiographic Region 5 is composed solely of the San Luis Valley. Less than 11 inches of annual precipitation are received in the region. The vegetation in the region is primarily grassland with a large component of agricultural use. The region is approximately 90% high permeability soils. The near surface geology is mostly un-lithified alluvium. Background soil salinity data was available for most of the region and a significant portion of the region has relatively high background soil salinity.

4.2 Physiographic Region Vegetation and Aquatic Life

The primary potential receptors for salt migrating off-site from salt pile facilities will be the soil itself, vegetation and aquatic life. This section discusses the dominant vegetation and aquatic life in each region.

· **Physiographic Region 1**

The natural vegetation in this region is dominated by arid shortgrass prairie communities of blue grama and buffalo grass. Crops grown in the area are primarily for pasture and forage species. Trees are rare except in local riparian areas. Aquatic species are primarily warm water species that can tolerate periodic low oxygen levels.

· **Physiographic Region 2**

The natural vegetation in this region is dominated by spruce-fir forest, Douglas fir, lodgepole pine, ponderosa pine, and a wide variety of alpine, subalpine and montane herbaceous and deciduous species. In addition, wetland communities are common in many of these areas. Aquatic species in this region are typically cold water species.

· **Physiographic Region 3**

The natural vegetation in this region is dominated by pinyon pine-juniper woodlands, grasslands, chapparal and shrublands. Aquatic species in this region are typically a mixture of cold and warm water species.

· **Physiographic Region 4**

The natural vegetation in this region is dominated by pinyon pine-juniper woodlands, ponderosa pine, chapparal and shrublands. Aquatic species in this region are typically warm water species.

· **Physiographic Region 5**

The natural vegetation in this region is dominated by grasslands, alkali flats and agricultural use. Aquatic species in this region are typically warm water species.

5.0 PROPOSED REGIONAL TOXICITY GUIDELINES

Toxicity information provided in Section 3.1 and 3.2.3 is segregated to reflect the major ecosystem species groups within the five regions of Colorado. For each major ecosystem group, ranges of toxicity values are listed in Table B5-1. Table B5-2 identifies general regional values that would be considered in the site-specific part of the overall ranking process for vegetation and aquatic life. Clearly, specific local species of vegetation and aquatic life would need to be considered as part of any specific facility investigation. For example, the presence or absence of cultivated crops could make a significant difference on acceptable soil salinity values at a specific facility.

Toxicity information for livestock watering (Section 3.2.2) and use of groundwater as drinking water (Section 3.3) would also be used in the site-specific part of the overall ranking process.

6.0 SITE-SPECIFIC EXPOSURE PATHWAY OBSERVATIONS

The regional evaluation provided in this report is a macro-level evaluation. Although, each salt pile storage area will be located within one of the designated physiographic regions and

Table B5-1
Physiographic Regional Salinity Tolerance Values

Physiographic Region	Typical Plant Species	Threshold Soil Salinity Tolerance (dS/m)	Typical Aquatic Species	Threshold Aquatic Salinity Tolerance	
				NaCl (mg/L)	dS/m
1	Blue grama grass (alkali sacaton)	16 to 20	warm water species (fathead minnow)	4000-6000	5 to 8
1	Buffalo grass	8			
1	Pasture and forage crops	8 to 16			
2	Spruce Fir	2 to 4	aquatic insects	4 to 7	0.01
2	Douglas Fir	2 to 4	trout	1000-1500	1 to 2
2	Lodgepole Pine	2 to 4			
2	Aspen	2 to 4			
2	Willow	4			
3	Pinyon pine	8	warm water species (fathead minnow)	4000-6000	5 to 8
3	Juniper	8	aquatic insects	4 to 7	0.01
3	Grassland	4 to 8	trout	1000-1500	1 to 2
3	Fruit and vegetable crops	2 to 4			
3	Pasture and forage crops	8 to 16			
4	Pinyon pine	8	warm water species (fathead minnow)	4000-6000	5 to 8
4	Juniper	8			
4	Creosote	10			
4	Silver buffalo berry	16			
5	Alkali grassland	14-18	warm water species (fathead minnow)	4000-6000	5 to 8
5	Pasture and forage crops	8 to 16			

Table B5-2
Physiographic Regional Salinity Guidelines

Physiographic Region	Proposed Regional Salinity Tolerance Guidelines		
	Soil	Aquatic	
	(dS/m)	(mg/L NaCl)	(dS/m)
1	8 to 16	4000-6000	5 to 8
2	2 to 4	4 to 7 (aquatic insects)	0.01
		1000-1500 (trout)	1 to 2
3	4 to 8	4 to 7 (aquatic insects)	0.01
		1000-1500 (trout)	1 to 2
4	8 to 10	4000-6000	5 to 8
5	10 to 15	4000-6000	5 to 8

associated with a particular ecosystem, it will also be necessary to incorporate site-specific data, knowledge and observations into the ranking system. As far as the potential for exposure is concerned, several site-specific aspects will be queried in the site-specific ranking system questionnaire:

- Soil (evidence of staining, erosion, drainage patterns)
- Terrestrial vegetation (major types, proximity to site, evidence of impacts)
- Terrestrial wildlife (especially small mammals, presence or absence, other evidence)
- Nearest water body (type, proximity to site, evidence of drainage from site into water body)
- Aquatic vegetation (presence or absence, proximity to site, evidence of impacts)
- Aquatic organisms (presence or absence, proximity to site, evidence of impacts)
- Nearest agricultural land use for crops or stock watering
- Nearest groundwater well and potential use of groundwater for drinking water

Attachment A provides more detail on the Salt Pile Facility Ranking Process that is currently being tested.

7.0 REFERENCES

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APPENDIX C

Tool and User Guide

C.1 INTRODUCTION

The ranking tool is a Microsoft Access 2000 based database that guides users through Steps One and Two of the ranking process through a graphic user interface (GUI). It is designed to be user friendly and can be used by anyone regardless of database experience.

C.2 SYSTEM REQUIREMENTS AND INSTALLATION

C.2.1 System Requirements

This application is designed to run on standard computers running Microsoft Windows software. The following components are required to run this application:

- CD-ROM drive
- Microsoft Access 2000
- 250MB of free hard disk space

C.2.2 Installation

To install the application,

- Insert the CDOT Salt Pile Priority Ranking System disc into the CD-ROM drive. Copy the Microsoft Access database titled “CDOT Salt Pile Priority Ranking System.mdb” to the local hard drive.
- Navigate to the folder where the database was copied, right click the database file and click on Properties in the shortcut menu. In the Properties window select the General tab and uncheck the Read-only attribute box.

C.3 Instructions for Use

C.3.1 Main Menu

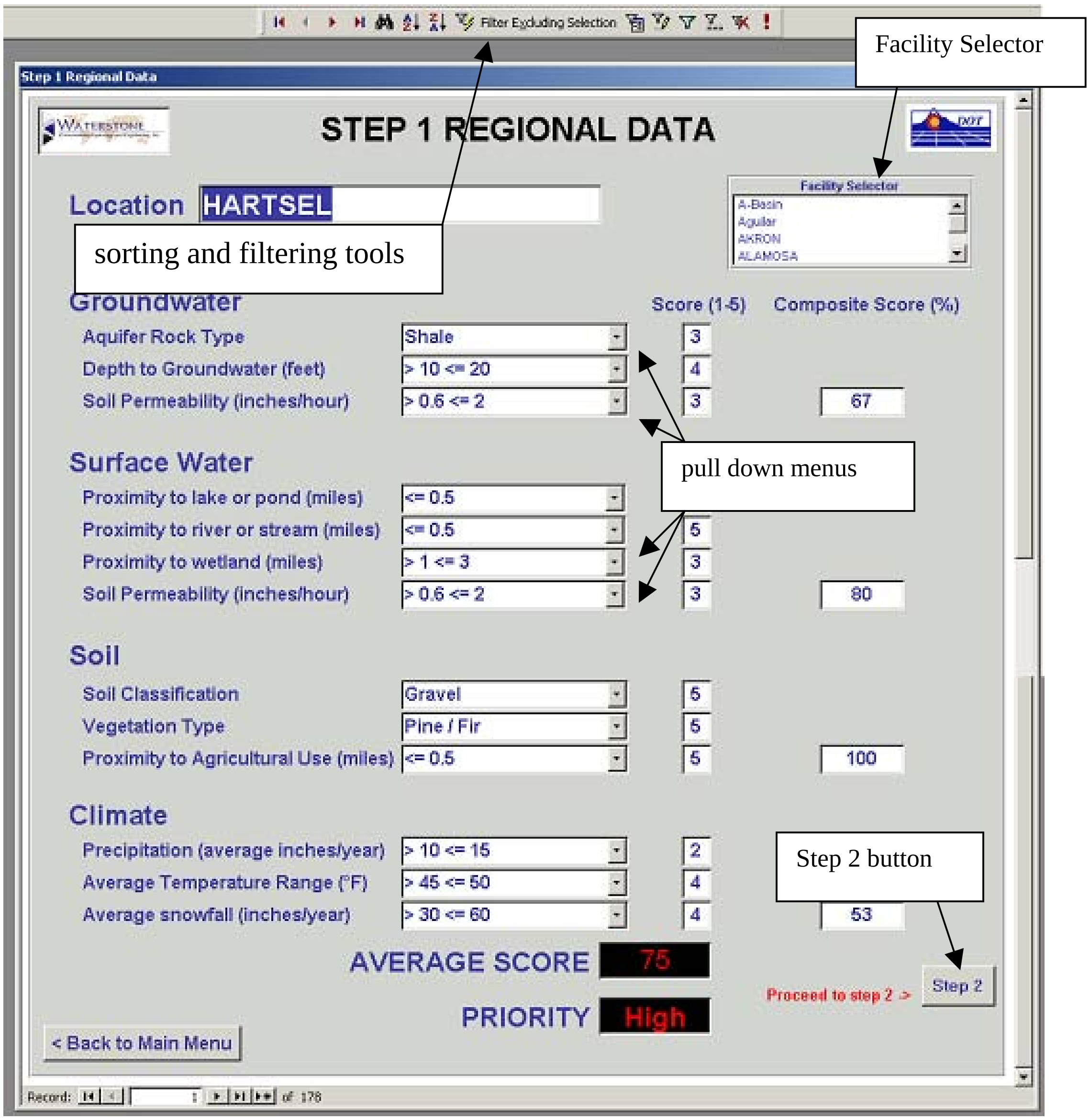
When starting the program, a splash screen will open for several seconds followed by the Main Menu.

Main Menu

From the Main Menu screen, users can proceed to Step One in the ranking process by clicking the top button or see the state map to reference the facilities by clicking the middle button. The third button will close the application and exit Microsoft Access.

C.3.2 Step 1 - Regional Data

The Step One screen has static data for each facility that cannot be edited. The user is able to view the results for each facility and proceed to Step Two if a facility has a high ranking. The user can also view the different ranges for each question under the main categories by clicking on the pull down menus. To choose a specific site, scroll in the Facility Selector box and click the facility desired. By clicking a specific site, the form will update itself to the selected facility. To exit this step and return to the Main Menu, click the button on the bottom left corner of the screen.



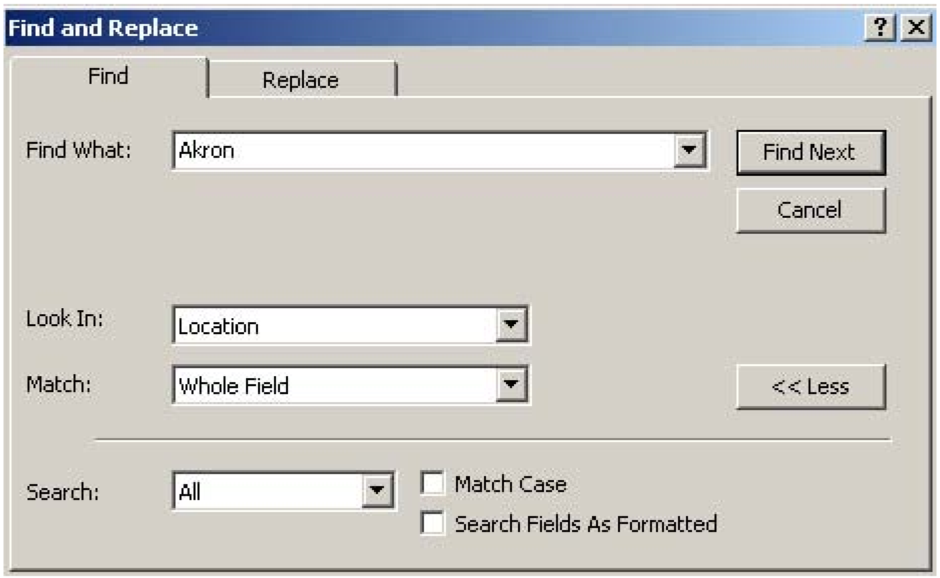
Step 1 Form

In Step One, facilities are pre-scored and ranked base on the information gathered from the GIS survey. Each category's composite score was calculated by determining its percentage of vulnerability out of 100, with a score of 100 having maximum scores of five for each question. The final average score for each facility was based on an average of the category's composite scores. The final average score determines whether the facility is a low, medium or high priority facility. Facilities with a score from 0 – 51 are low, 52 – 62 are medium and 63 – 100 are high priority facilities that prompts the user to proceed to Step Two. The Step 2 button will only be visible if the facility is ranked as a high priority site.

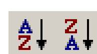
The Step One form also has sorting and filtering tools in the menu bar at the top of the screen. Users can sort and filter for a specific facility, total score, priority, specific answer to any categorical question or any combination of these. This is useful to sort facilities in order of total score, to only see facilities that have a high priority, or, for example, to see facilities that only have a gravel soil classification.

Starting from the left end of the toolbar there are four arrow buttons. 
These are used to go to the first, previous, next or last record.

The next button shows a pair of binoculars.  This button is a Find button. Clicking it will bring up the conventional "find" dialog box.



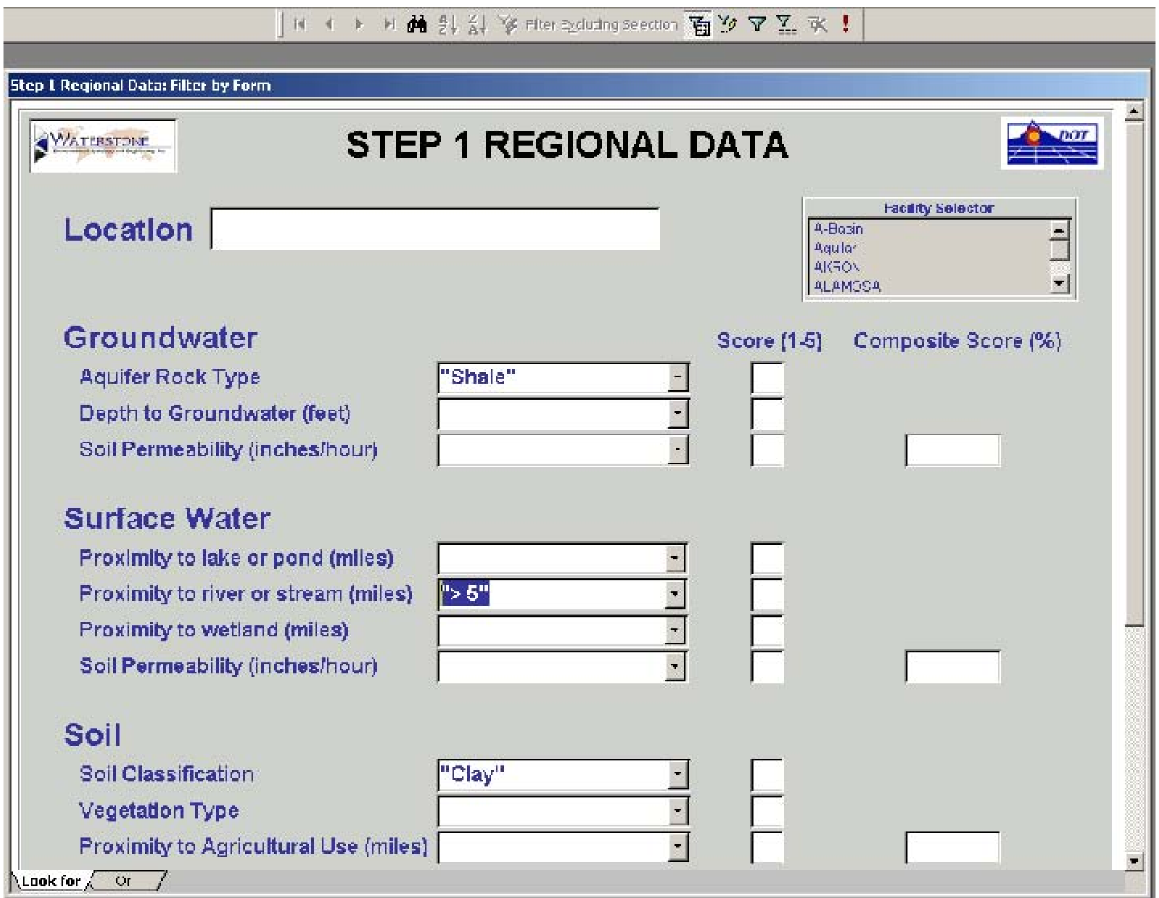
This “find” option can be used to find specific items or values in any of the fields. The “Replace” tab will not work because the data is protected and static. To search in a specific field, select the field prior to clicking the find button. Almost all of the fields are searchable, except the individual and composite scores.

The A to Z and Z to A buttons are for data sorting.  Like the Find button, users can click on almost all of the fields except the individual and composite site scores and sort the data in ascending or descending order.

The next two buttons are for filtering according to a chosen field 

. By clicking the first button titled Filter by Selection that has a filter and lightning bolt as its icon, only the records that are equivalent to the currently selected field will be shown. For example, a user may want to only see sites that have an aquifer rock type of “Sand / Gravel”. The user goes to a record that has a “Sand / Gravel” aquifer rock type, clicks on that field, then clicks on the filter button. To remove the filter so that all the records appear, the user can click the Apply/Remove Filter toggle button  and all the records will appear again. The Filter Excluding Selection button will do the opposite. Instead of showing all records that have a field value equivalent to the selected field value, it will show all records except records equivalent to the selected field. In the example above, all records will be shown that do not have "Sand / Gravel" as an aquifer type.

The Filter by Form button  is similar to the Filter by Selection button. However, this button allows the user to filter with multiple criteria. When clicking this button, all the fields become blank, allowing the user to choose criteria. Users can also use the "Or" option of querying by selecting the tabs on the bottom left corner of the screen.



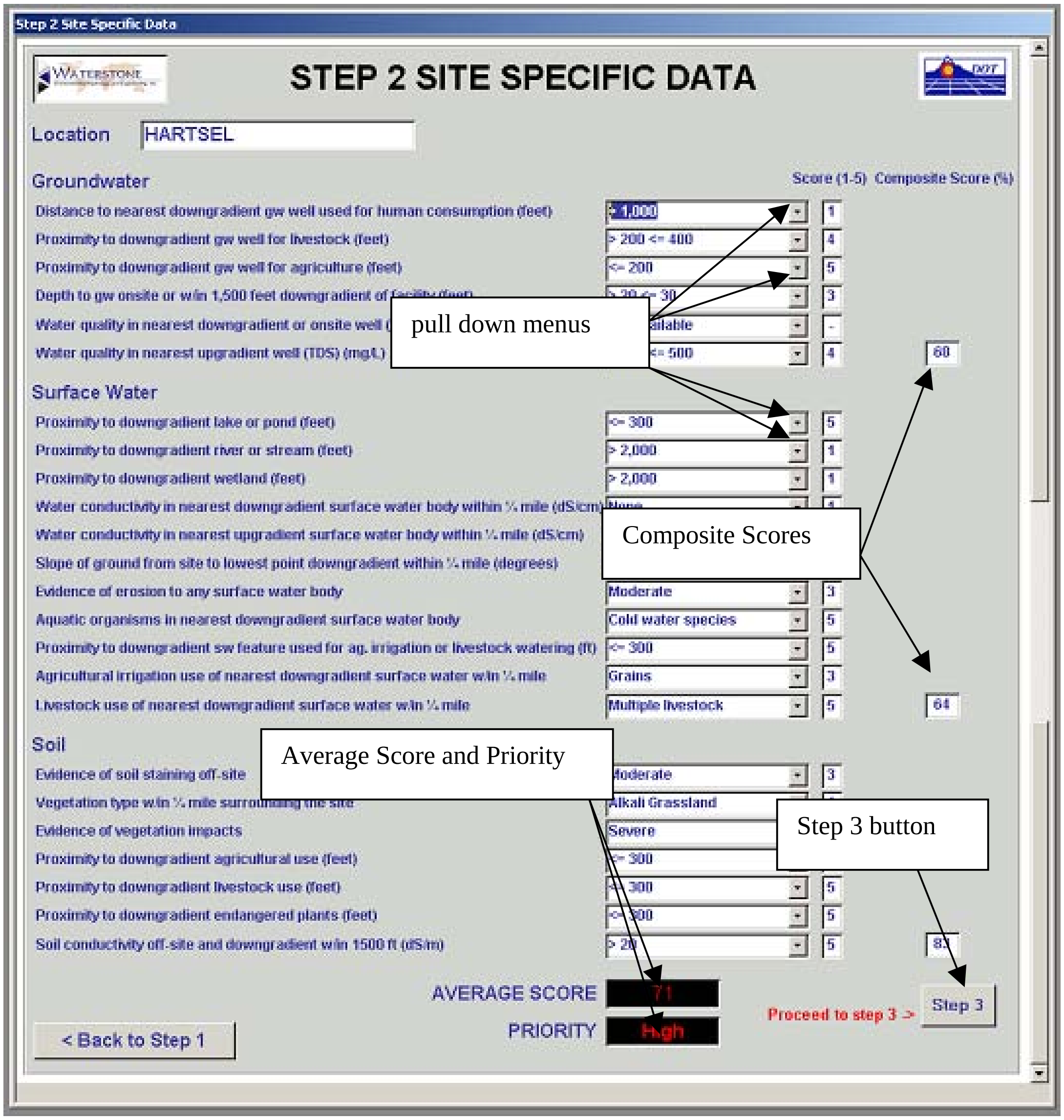
In the example above, the Filter by Form option is being used to show only sites that have a "Shale" Aquifer rock type, ">5" for Proximity to river or stream (miles), and "Clay" for the Soil Classification. After choosing the criteria, clicking on the Apply/Remove Filter button will give the user the results. Clicking the Apply/Remove Filter button again will show all records.

The Advanced Filter/Sort options   allow users to modify a query in Microsoft Access query design view, apply the newly designed query or remove it. Using this option is for advanced Microsoft Access users.

C.3.3 Step Two – Site Specific Data

Users are prompted to enter information in Step Two for high priority facilities. The location box at the top will be automatically populated when proceeding from Step One. It is the user's responsibility to conduct a facility survey to fill out the rest of the form. This will allows the program to automatically calculate the site's total average score in real time and determine the facility's ranking. The scoring is identical to Step One with categories having composite scores based on a percentage and a total average score based on an average of the category's composite scores.

To complete the form, answer the questions by selecting the pull down menus and choosing one of the options for each question. There are 25 total questions broken down into groundwater, surface water, and soil. After each category is completed, a composite score is calculated. After all the categories are completed, a final average score and priority is determined for the site. Once all the questions are answered, users can go back and change their values for each question and see the composite scores, final average score, and priority recalculate itself according to the new values. To return to Step One click the button on the bottom left corner of the screen. Facilities with a score from 0 – 45 are low, 46 – 65 are medium and 66 – 100 are high. If the facility is a high priority site a Step 3 button will be visible to prompt the user to proceed.



Step 2 Form

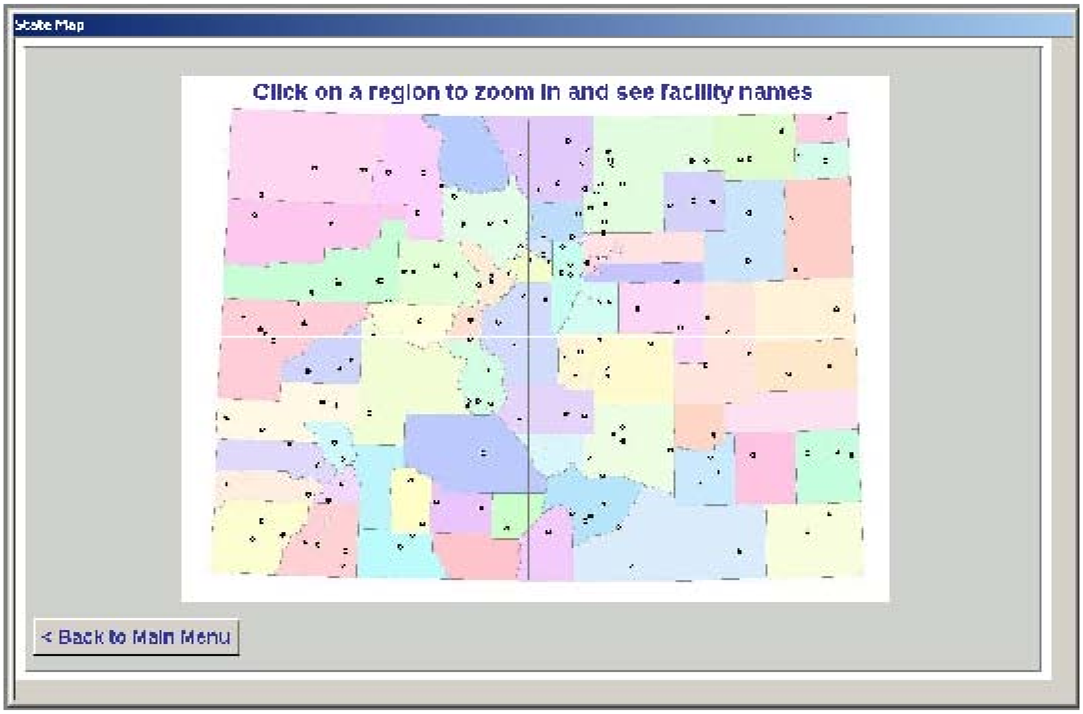
C.3.4 Step Three – Onsite Investigation

If a user receives a high score they are prompted to go to Step 3 where the screen will only instruct the user to conduct an onsite investigation. To return to Step 2 click on the button on the bottom of the screen.

Step 3 Form

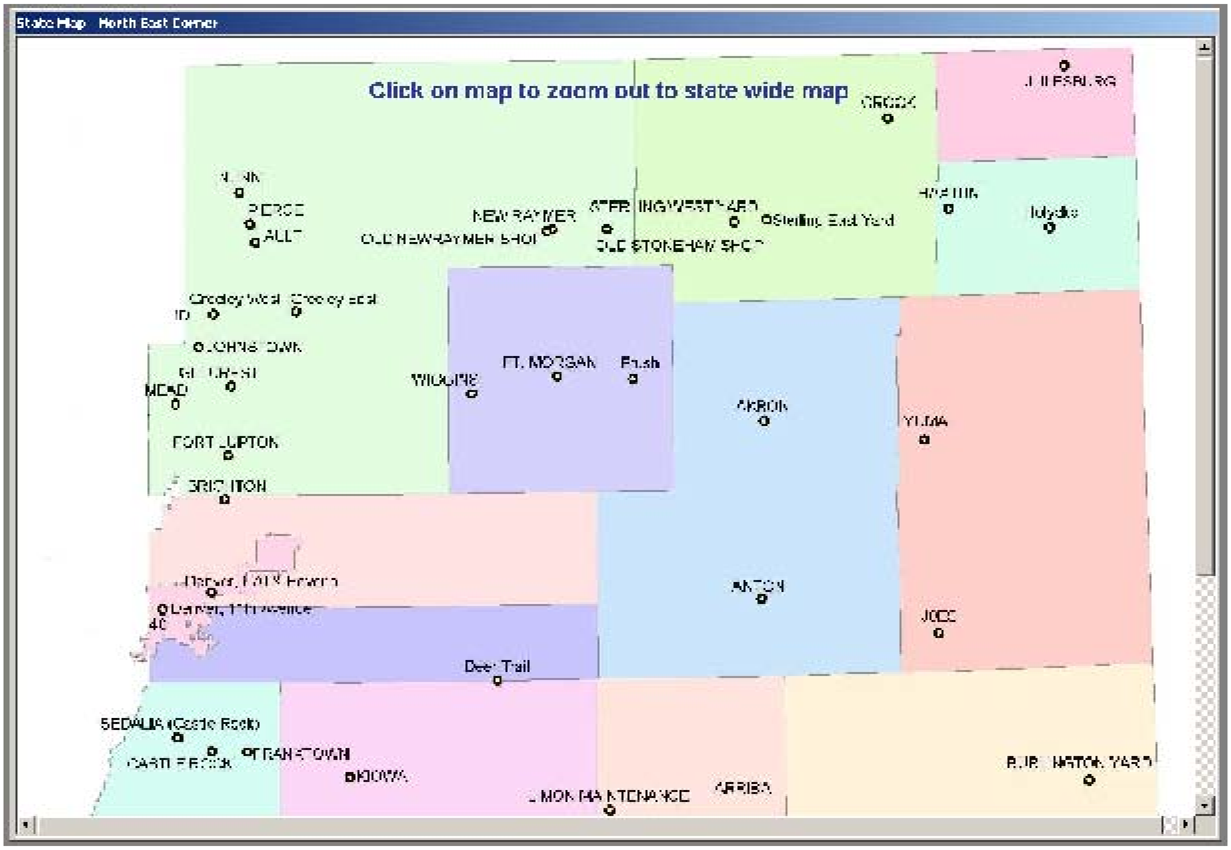
C.3.5 State Map With Facilities

Selecting the second button from the Main Menu titled "State Map With Facilities" will take the user to a state map with yellow dots for all the state facilities as shown below.



State Map

Users can click a region on the map and zoom into one of four quadrants to see the corresponding facilities with their names for a reference as shown below. Users can also return to the Main Menu by clicking the button in the bottom left corner.



State Map – North East Quadrant

To return to the state wide map from any of the quadrants, click anywhere on the map.