COLORADO
Department of Transportation

DTD Applied Research and Innovation Branch

# Assessment of CDOT Revegetation Practices for Highway Construction Sites

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**Report No. CDOT-2015-02**
**February, 2015**

## Technical Report Documentation Page

1. Report No.
CDOT-2015-02

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Assessment of CDOT Revegetation Practices for Highway Construction Sites

5. Report Date
02/18/2015

6. Performing Organization Code

7. Author(s)
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8. Performing Organization Report No.
CDOT-2015-02

9. Performing Organization Name and Address
TerraLogic LLC
5766 Flagstaff Road
Boulder, Colorado 80302

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
Colorado Department of Transportation - Research
4201 E. Arkansas Ave.
Denver, CO 80222

13. Type of Report and Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes
Prepared in cooperation with the US Department of Transportation, Federal Highway Administration

16. Abstract

The revegetation of previously disturbed areas from highway construction activities is a critical component to overall site stormwater management strategy. Poor revegetation actions during and after construction can lead to difficulty in deactivating stormwater construction permits (SCPs). Excessive duration of open permits due to poor revegetation success can result in higher non-project costs for erosion control, revegetation rework and maintenance, and regulatory compliance monitoring and documentation. Open SCPs can increase the potential for regulatory inspections and fines. Unexpected rework and liability costs can be experienced by CDOT maintenance who is responsible for SCP compliance.

A research project was conducted by the Colorado Department of Transportation (CDOT) to assess the effectiveness of the CDOT revegetation process and associated specifications. The research study developed five hypotheses that were tested using field observation and testing approaches. Active construction projects' revegetation practices were observed using a quality control approach. Revegetation success on former construction sites was tested using a "forensic" approach by measuring and observing critical revegetation establishment variables. An informational survey was conducted to assess the CDOT construction engineering understanding of the CDOT revegetation process. A cost evaluation was performed to determine the financial impact of not initially performing revegetation correctly that required rework and the maintenance cost associated with achieving SCP deactivation.

There are over thirty conclusions and associated recommendation provided in this report to improve CDOT revegetation success, including improved testing; salvage and amendments to topsoil to improve nutrient and organic concentrations; improved quality control by landscape architects or landscape architect's qualified revegetation representative during the construction and revegetation process; improved education or outreach to ensure a basic understanding of revegetation processes within project managers who are not landscape architects; and better tracking of short and long term costs of vegetation repairs after project completion, but before permit deactivation.

To achieve improved revegetation efficiency will require CDOT to prioritize and implement several of these recommendations. Areas needing significant improvement include: vegetation process quality control, contractor compliance to CDOT specifications, understanding of the CDOT revegetation process and specifications by contractors and CDOT field personnel, the post-construction process of managing contractor contracts related to unsuccessful vegetation, and consistent protocols for revegetation expectations related to project hand-over and SCP deactivations.

| 17. Keywords<br>Revegetation, Stormwater Construction Permit (SCP) deactivation, maintenance costs, revegetation specifications, quality control, resource costs. | | 18. Distribution Statement<br>This document is available on CDOT's website http://www.coloradodot.info/programs/research/pdfs | |
|---|---|---|---|
| 19. Security Classif. (of this report)<br>Unclassified | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages | 22. Price |

**Form DOT F 1700.7** (8-72) Reproduction of completed page authorized

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February 18, 2015

## ACKNOWLEDGEMENTS:

The authors would like to thank the following individuals for their help with this research study.

- Mike Banovich, CDOT Ecological Design and Landscape Unit Manager
- Bryan Roeder, Environmental Research Program Area Manager for CDOT Applied Research and Innovation Branch
- Tom Boyce, Manager Hydrologic Resources and Ecological Design
- Ken Howlett, CDOT Region 1 Maintenance
- Jennifer Klaetsch, CDOT Region 3 Landscape Architect-Landscape Specialist
- Belinda Arbogast, CDOT Region 1 Senior Environmental Planner
- Fran Mallonnee, CDOT Region 5 Environmental, Water Pollution Control Manager
- Greg Fischer, CDOT EPB Landscape Architect
- Basil Ryer, CDOT EPB Landscape Architect
- Mark Humphrey, CDOT R2 Environmental Specialist
- Gary Spinuzzi, Water Pollution Control Manager, Region 3
- Steve Mulqueen, Water Pollution Control Manager, Region 1
- Jennifer Gorek, Water Pollution Control Manager, Region 4
- Sonya Erickson, Water Pollution Control Manager, Region 2
- Denise Wilson, Wilson Associates
- Joe Schneider, Western States Reclamation
- David Chenoweth, Western States Reclamation

# EXECUTIVE SUMMARY

The Colorado Department of Transportation (CDOT) Executive Directive Policy 27 under Chief Engineer Tim Harris (March, 2012) identified that the CDOT Maintenance Division would be responsible for the compliance to the Colorado Department of Public Health and Environment's (CDPHE) Stormwater Construction Permit (SCP) after construction is completed. CDOT maintenance was identified to be legally responsible for the compliance to the SCP terms and conditions by formally accepting the transferring of the permit from the prime contractor. It is also CDOT maintenance's responsibility to ensure effective vegetation has been established and maintained by the landscape contractor in order to deactivate the SCP. For innovative contracting projects, the Regional Transportation Director or the prime contactor's management should be identified as the Compliance Manager for the revegetation life cycle of the project.

Critical to successful deactivation of the SCP is the establishment and maintenance of plant revegetation within areas disturbed by construction activities (site reclamation). The SCP permit deactivation requires that vegetative cover is established to 70 percent of pre-construction vegetative cover conditions. The longer the SCP permit remains active the more CDOT financial resources and personnel are necessary to maintain compliance to permit conditions, and environmental and regulatory risk and liability to CDOT also increases.

The success of the CDOT revegetation (reclamation) process is critical to address these cost and risk issues; therefore, this research project was developed to assess the current CDOT revegetation specifications and processes, and to develop scientifically valid vegetation technologies to reduce the time necessary to achieve SCP deactivation and final site stabilization.

The objectives of this research study were to provide recommendations related to CDOT's existing revegetation methodologies, processes, and specifications; in order to provide better, faster, more efficient and ecologically specific revegetation of ground disturbed by construction activities. This was conducted through investigation of five basic research hypotheses related to revegetation. These hypotheses were tested using revegetation interviews, QC assessments, salvaged soil testing, top soil characterization, seed viability testing, forensic vegetative surveys, maintenance revegetation cost assessments, and a construction engineering survey . The following are the results of the hypothesis testing:

- Salvage Soil Management Hypothesis- The potential for improved plant reclamation can be achieved if nutrient and organic amendment concentrations of topsoil are known before vegetation actions initiate. It was identified that nutrient addition is not normally required for all the soils sampled in this study. There was a need for additional compost material for higher organic matter concentrations to promote plant growth. Proper topsoil removal and management was shown to be effective in promoting revegetation.
- Construction Revegetation Quality Control Hypothesis- The CDOT revegetation process is not being completely followed especially at critical steps; and therefore the lack of compliance is negatively affecting the rate, quality and overall success of vegetation. This hypothesis was proven correct for most active construction sites visited in this research project. There is a lack of revegetation quality control performed by landscape architects or qualified reclamation professionals.

- Forensic Revegetation Analysis Hypothesis- Improved revegetation will occur if contractors follow specifications and contract requirements based on historical evidence. This hypothesis was proven correct based on the forensic surveys performed at former construction sites. Proper soil preparation, amendments and seeding were deemed critical in the CDOT process success. Forensic studies revealed minimal evidence of soil erosion where the project had adequate conditions to establish plant growth.
- Revegetation Survey of CDOT Construction Project Engineers– The majority of CDOT Construction and Design Engineering representatives lack basic technical and process knowledge to successfully manage and direct vegetation and landscape activities. This hypothesis was correct based on conversations with CDOT landscape architects, RWPCMs and the results of the engineering survey.
- Revegetation Cost Analysis- CDOT Engineering and Maintenance management has underestimated the cost and effort for project revegetation and resulting rework. Due to the lack of accurate data, this hypothesis was neither proven nor disproven. It is evident that a high amount of financial resources are being used for vegetation monitoring and repair based on CDOT Region 1 data.

This project focused on two field investigation techniques. The first technique was the Construction QC Process, where five active construction sites' revegetation strategies were observed. The second technique was a termed a "forensic" based approach, and involved evaluation of the vegetation success of five previous construction sites.

There are numerous cost benefits associated with the recommended improvements to the CDOT revegetation process. Cost benefits can be realized throughout the life cycle of the vegetation process involving roadway design, construction, and post-construction phases. Much of these cost benefits would be realized by CDOT maintenance, who bears the responsibilities for SCP compliance to permit deactivation. The follow items are associated with the main cost benefits:

The cost of not installing and correctly maintaining vegetation correctly the first time results in potentially expensive vegetation rework by CDOT maintenance in order to achieve the vegetation cover necessary for permit deactivation; CDOT Region 1 has realized non-project rework costs of over $660,000 for twelve projects.

Poor vegetation installation and maintenance during roadway construction can lead to an unnecessary length of time the SCP needs to remain active. This excessive time requires additional resources to provide regulatory compliance management activities such as erosion control, regulatory monitoring, documentation, and revegetation maintenance. The longer the SCP is open, the more time CDOT is managing environmental and regulatory risks.

Several reclamation strategies are recommended for CDOT that are more cost effective for construction site revegetation. The new strategies involve using seed mixes that are based on site specific native plant communities. Poor vegetative establishment and diversity using existing seed mix strategies has been observed on previous construction sites. There should be less pure live seed applied to the soil surface during seeding; current seeding applications are two to three times higher than needed. Improved cost savings can be realized from these two strategies.

There are over thirty conclusions and associated recommendations provided in this report to improve CDOT revegetation success. To achieve improved vegetation efficiency, will require CDOT to prioritize and implement several recommendations. The revegetation challenges facing CDOT involve many areas such as process quality control, contractor compliance to CDOT specifications, understanding of the CDOT revegetation process and specifications by contractors and CDOT field personnel, and the lack of a post-construction process in which inconsistent methods, protocols, and compliance are used for contractor contracts and associated revegetation expectations and SCP deactivations.

### *Implementation Statement*

It will require a coordinated effort among numerous CDOT representatives and regions to identify the recommendations that reduce the most overall risk to CDOT. Provided is a list of recommendations and a potential means of prioritizing them. Implementation will also require support from CDOT upper management in engineering and maintenance program areas. The recommendations provided may be best suited for a top-down management approach; or a bottom-up education-training approach, therefore, we recommend identification of a Revegetation Program Champion. For top-down approaches such as improving compliance, and quality control, this Program Champion could work with the CDOT regional Transportation Directors (RTDs), or the Director of Highway Maintenance, all of whom could benefit from cost and staff-time savings associated with vegetation re-work. For bottom-up approaches the Program Champion could use formal training, specification changes, or other methods as an opportunity to improve staff knowledge of correct methods, processes, and specifications.

The implementation of the provided recommendations should also integrate performance measures to assess vegetation improvement and success. An implementation plan should follow an Environmental Management System (EMS) approach using the Plan-Do-Check-Act methodology. It is expected that a CDOT management champion will be acquired to support the program and provide programmatic guidance.

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# ACRONYMS LIST

| | |
|---|---|
| AOSA | Association of Official Seed Analysts |
| BMP | Best Management Practice |
| BLM | Bureau of Land Management |
| CDPHE | Colorado Department of Public Health and Environment |
| CDOT | Colorado Department of Transportation |
| DOT | Department of Transportation |
| DTD | Department of Transportation Development |
| EC | Electrical Conductivity |
| EPB | Environmental Programs Branch |
| FHWA | Federal Highway Administration |
| IWMP | Integrated Noxious Weed Management Plan |
| NRCS | Natural Resource Conservation Service |
| NEPA | National Environmental Policy Act |
| N-P-K | Nitrogen-Phosphorous-Potassium |
| OM | Organic Matter |
| PLS | Pure Live Seed |
| QA | Quality Assurance |
| QC | Quality Control |
| RECAT | Regional Erosion Control Assessment Team |
| RWPCM | Regional Water Pollution Control Manager |
| RFP | Request for Proposal |
| ROW | Right-of-Way |
| SAP | Systems, Applications, and Products |
| SAR | Sodium Absorption Ratio |
| SCP | Stormwater Construction Permit |
| SWMP | Stormwater Management Plan |
| TECS | Transportation Erosion Control Supervisor |
| USDA | United States Department of Agriculture |

# 1.0 INTRODUCTION

Proper stormwater management is an important component of any Colorado Department of Transportation (CDOT) construction project. Stormwater management at a project level is an integration of many components such Stormwater Construction Permit (SCP) acquisition and compliance, landscape and roadway design, grading, development and maintenance of erosion-control best management practices (BMPs), CDOT specification compliance, and Transportation Erosion Control Supervisor (TECS), and the development and oversight of the Stormwater Management Plan (SWMP). One of the most critical parts of successful stormwater management that is often overlooked is the development and execution of a comprehensive landscape design plan to achieve final site stabilization after construction. A successful landscape strategy and plan will reduce CDOT's environmental liability, protect water quality, reduce the time for plant establishment and site stabilization, keep productive soils onsite, and reduce long term maintenance costs.

After significant ground disturbance, revegetation is the establishment of desirable plant species that stabilize. soil, reduce erosion and provide diverse plant species that match the local ecology. In recent years, the Federal Highway Administration (FHWA) and CDOT have been moving beyond regulation-driven stormwater based mitigation approaches and into proactive environmental stewardship strategies to promote healthy ecosystems. Native plants are a foundation of ecological health and function in natural environments. Roadside revegetation with native plants is a key practice for managing environmental impacts and improving conditions for healthy ecosystems. In addition, native plants along roadsides provide economic, safety, and aesthetic advantages. Well-planned, sustainable, native vegetation supports transportation goals for safety and efficiency by stabilizing slopes, reinforcing infrastructure, and improving the road user's experience by creating natural beauty and diversity along the roadside (FHWA, 2007).

Desirable plants are both native and non-native species that have sufficient root structure and vegetative growth to prevent soil detachment during rainstorms and help prevent soil erosion, transport, and deposition. It is CDOT policy to conserve water and reduce maintenance costs on landscaped highway segments through the use of native or dry land adaptable plant materials (CDOT, 1977). Therefore, native plant selection and establishment is important in promoting a consistent plant community based on a given ecozone region within the CDOT Right of Way (ROW). Native plants also provide desirable visual enhancement to the traveling public and promote pollinator viability. Revegetation is a complex and important component in the overall CDOT construction and post-construction process. Conducting revegetation in an appropriate manner will protect local water quality resources, improve environment quality and decrease overall maintenance costs.

A project revegetation strategy that stresses proper site stabilization in the form of plant establishment is a CDOT requirement through the CDOT Standard Specifications for Road and Bridge Construction (CDOT, 2011) and a requirement by the Colorado Department of Public

Health and Environment (CDPHE). To achieve final and sustainable construction site stabilization the project area must have appropriate soil preparation, grading techniques, soil amendments, mulching and native plant selection and installation.

Revegetation is an important regulatory and CDOT Specification compliance element. According to the CDOT Municipal Separate Stormwater Sewer System (MS4) Permit's Construction Program (CDPHE, 2012) and the Colorado Discharge Permit System Regulation for Stormwater Permitting (CDPHE, 2007) (5 CCR 1002-61) a stormwater construction permit (SCP) must be obtained at least 10 days prior to the initiation of construction. A condition of obtaining this SCP is the development and implementation of a SWMP. CDOT has established an extensive template for the development of a SWMP for CDOT Construction Projects. The CDOT SWMP Interim and Final Stabilization requirements identify the following elements (CDOT, 2014):

- Seeding plan
- Seeding application
- Mulching application
- Special requirements (due to high failure rates)
- Soil conditioning and fertilizer requirements
- Erosion control blanket application
- Re-seeding operations/corrective stabilization
- Pre-construction and post-construction vegetative cover/density determination

CDOT specifications are very specific in regards to final site stabilization methods. CDOT specifications address the following areas for construction site revegetation (CDOT, 2011):

- Seeding, fertilizer, soil conditioner, and sodding (Section 212)
- Mulching (Section 213)
- Planting (Section 214)
- Transplanting (Section 215)
- Soil retention covering (Section 216)

According to CDPHE regulations, the project site must continue to be monitored, formally documented and BMPs maintained by the permit holder to protect local water resources until the SCP is deactivated. By following the current CDOT revegetation process, specifications, policies and guidance, it can take a significant amount of time and resources to reach permit deactivation via the 70 percent-vegetative ground cover criteria, depending on the eco-region in which the project resides. Waiting years to deactivate the SCP increases costs and environmental risk and liability to CDOT. Post-construction site monitoring is generally performed or directed by CDOT maintenance representatives who have formally taken over the responsibility for the SCP compliance and management. Monitoring and BMP maintenance activities on post-construction sites require CDOT regions to schedule and use valuable professional and financial resources to meet the SCP requirements, avoid notices of violation, and protect water quality. There have been observed conditions in which vegetation success has been compromised due to poor seed selection and installation, lack of soil preparation and amendments, lack of process monitoring and poor compliance to CDOT specifications by the contractor. As a result, expensive revegetation rework and prolonged CDOT maintenance management have to be used to maintain compliance, stabilize the site and ultimately deactivate the SCP.

## 1.1 Project Goals and Objectives

The focus of the Assessment of CDOT Revegetation Practices for Highway Construction Sites Project (Project) is to identify, assess and evaluate critical operational and environmental variables necessary to obtain optimum establishment of desirable ground cover vegetation and density within a reasonable amount of time possible for permit deactivation and site stabilization. The Project goals and objectives were as follows:

### ***Project Goals***

- Provide a list of potential revegetation practices derived from other states, research experts and CDOT specialists that CDOT can implement for revegetation success within a reasonable timeframe.
- Categorize the potential revegetation changes based on risk and the timeframe required to implement those changes at a regional level.
- Identify and evaluate revegetation practices that will significantly reduce the revegetation specification modifications and the time necessary to achieve SCP deactivation and sustainable site stabilization for construction sites.
- Identify and evaluate more efficient revegetation practices that would minimize the financial and professional resources needed for regulatory compliance, site monitoring and water quality protection.
- Identify revegetation practices that take into account and consider sustainable site stabilization conditions that include potential climate change.
- Identify and recommend revegetation practice improvements and enhancements that can be of immediate use to all CDOT regions.

### ***Project Objectives***

The Project objectives developed by the Project Research team was to identify, evaluate and recommend the implementation of research-based revegetation strategies and assess existing CDOT specifications and revegetation process to:

- Improve quality control of stabilization practices in design and construction thereby reducing time to reach project site stabilization thus reducing CDOT costs.
- Reduce the potential for CDOT notice of violations or corrective actions by reducing SCP durations.
- Select native plant species and seeding rates consistent with local ecozone characteristics and climate change projections.
- Identify landscape actions and guidelines to reduce maintenance costs and resource utilization.
- Reduce project area soil loss, maintain land productivity, and protect local water resources.
- Identify potential revegetation process deficiencies and training requirements.

- Develop contractor coordination and monitoring approaches to improve revegetation success.
- Improve ROW ecological conditions by using native plants that benefit insect pollinators and overall ecological health.
- Reduce revegetation life-cycle costs and recommend effective post-construction practices.
- Identify revegetation enhancements and modifications that will eventually be incorporated into new CDOT landscape specifications.

## 1.2 Project Scope of Work

The universe of variables that could be studied and researched to improve CDOT's overall site revegetation methodology and process is extensive, including variables in seed selection, planting, soil amendments, timing, contracting, performance management, and many more. This report will discuss the approach used by the Project Research team to identify and select key revegetation-based research variables to meet the goals and objectives of the study. A revegetation literature search and a research alternatives analysis process was developed and executed that screened the number of research variables to a manageable level. The alternative analysis methodology is described in Section 2.0.

The selected project scope of work focused on the following five research elements:

- Construction Revegetation Quality Control
- Stockpile Management
- Forensic Vegetative Field Studies
- Revegetation Survey of CDOT Construction Project Engineers
- Revegetation Cost Analysis

## 1.3 Project Research Team and Study Panel

The Project Research team was comprised of CDOT representatives who are directly involved with construction erosion control, revegetation and final site stabilization such as CDOT landscape architects and environmental consultants specializing in stormwater management, soil science, agronomy, transportation sustainability, plant identification, and revegetation. The team members worked closely together in developing the research scope of work and technical approach, conducting field visits and acquiring technical information.

The CDOT Research team was comprised of Michael Banovich, RLA, CPESC as the Technical Lead. Banovich is the Ecological Design Unit Manager; he provided direction and technical oversight for the project. Banovich has over 30 years of revegetation and erosion control experience for CDOT. Bryan Roeder is the Environmental Research Program Area Manager for CDOT Department of Transportation Development (DTD), Applied Research and Innovation Branch, and was the overall project manager. Roeder has extensive experience in terrestrial ecology, wildlife biology, study design, and research. He was CDOT's representative in a related 2011 project, "Current and Innovative Solutions to Roadside Vegetation Using Domestic Plants; A Domestic Scan Report" (see References). CDOT landscape architects Basil Ryer and Greg Fischer provided field coordination, data collection and field observational support.

TerraLogic, LLC (TerraLogic) was the primary contractor hired by CDOT to conduct this research. The TerraLogic team was a compilation of professionals knowledgeable in the areas of soil science/agronomy, revegetation, plant identification, CDOT construction and maintenance practices and stormwater management. The TerraLogic team was comprised of Aaron DeJoia (Duraroot, LLC) who is a soil scientist and reclamation expert, Joe Schneider and David Chenoweth (Western States Reclamation) who are experienced in construction site revegetation and Denise Wilson (Wilson Associates) who is a vegetation identification specialist. Art Hirsch (TerraLogic), who has expertise in stormwater management and CDOT Construction and Maintenance Operations, was the Principal Investigator.

The CDOT Technical Lead and Project Manager identified several CDOT representatives who are experienced in construction and post-construction revegetation to be members of the study panel. The study panel members' responsibilities were to provide the CDOT Technical Lead and Project Manager with technical insight, support, direction and document review. Many of these panel members coordinated site visits and searched for revegetation documentation to support the TerraLogic team.

### 1.4 Report Elements

This research and development report is comprised of seven technical tasks that were based on the Request for Proposal (RFP) Scope of Work and research work elements that evolved primarily from performing Tasks 1 through Task 3. Tasks 1 and 2 were informational gathering activities that identified various potential research variables to study. Task 3 was an alternative analysis that identified the research variables for ultimate study and developed the overall project study plan. Tasks 4 A-D involved the execution of the scope of work elements.

- Literature Search (Task 1)
- CDOT Revegetation Specification and Process Evaluation (Task 2)
- Research Scope Alternatives Analysis/Field Testing and Methodology Plan (Task 3)
- Construction Revegetation Quality Control and Stockpile Management (Task 4A)
- Forensic Field Studies (Task 4B)
- Revegetation Survey of CDOT Construction Project Engineers (Task 4C)
- Cost Analysis (Task 4D)

As an organizational note, some of the appendices cited throughout this document will reside in the attached compact disc due to their length. The reader is urged to reference the table of contents or the appendices section to locate and review the appendix of interest.

## 2.0 METHODOLOGY

The research methodology was a combination of literature search, telephone conversations with CDOT regional Water Pollution Control Managers (RWPCMs) and regional state Departments of Transportations' (DOTs) landscape architects. This research information set the stage for an alternative analysis of research variables that would be tested and evaluated under field conditions.

A Field Testing and Methodology Plan was developed that directed the field studies for the Construction Revegetation Quality Control, Stockpile Management, and Forensic Field Studies. A CDOT Revegetation Survey of CDOT Construction Project Engineers' methodology was also developed that identified the basic level of revegetation understanding and process knowledge by CDOT construction engineers.

## 2.1 Literature Search (Task 1)

The TerraLogic team conducted a literature review of available practices and products that can potentially enhance and lead to quicker revegetation success. Task 1 was a combination of literature searches, telephone conversations with CDOT RWPCMs and regional state DOTs landscape architects. This research information set the stage for an alternative analysis of revegetation-based research variables that could be tested and evaluated under field conditions.

The goal of the Task 1 Literature Search was to identify and evaluate emerging trends, innovative products and techniques, and proven management techniques that both enhance revegetation success and are cost effective.

The research variables reviewed included specific plant biological, and soil characteristics, and the potential interactions between these variables. Strategies to enhance and modify these plant, biological, and soil variables and associated implementation strategies were considered for field testing due to their potential to increase revegetation success.

The second component of the Task 1 Literature Review was to review revegetation programs from other state DOTs and agencies. The TerraLogic team contacted and surveyed other states' key DOT landscaping and revegetation personnel via telephone to determine what they consider effective and ineffective revegetation practices. The DOTs were selected based on regional similarities that they share with Colorado (i.e. climatic conditions, terrain, and soil condition).

The third component of the Task 1 Literature Review was to conduct interviews with key CDOT personnel identified by the CDOT Project Manager and study panel who were familiar with the CDOT revegetation process, specifications, and stormwater management protocols. These interviews were conducted to determine current CDOT revegetation practices and which revegetation practices are and are not working effectively in the field.

## 2.2 CDOT Revegetation Specifications and Process Evaluation (Task 2)

Concurrent with Task 1, the TerraLogic team reviewed and evaluated the current CDOT specifications, processes, and guidelines for construction site revegetation. The purpose of Task 2 was to establish a baseline reference point to evaluate new and innovative approaches and revegetation strategies. The evaluation was performed using the following actions:

- CDOT specifications were critically reviewed and critiqued by TerraLogic team member, Western States Reclamation, in light of their experience and practical application of the specifications

- Revegetation specifications and guidance from DOTs within the Intermountain West were reviewed and assessed against the existing CDOT specifications

The information collected and the recommendations developed from Tasks 1 and 2 were compiled and summarized in Appendix A. This appendix contains information obtained from research-based literature review, information obtained from both CDOT and regional state DOT references and the critique of CDOT specifications.

## 2.3 Research Scope Alternatives Analysis (Task 3a)

Task 1 and Task 2 provided the foundation necessary towards the ultimate selection of the Project's research test variables. The number of potential research variables to promote enhanced revegetation was large and required an alternatives analysis approach to reduce them to a manageable number that could meet the Project goals. The alterative analysis methodology was conducted in concert and with close coordination with the Project study panel. Ultimately the alternatives analysis reduced the number of the potential research variables from 100 to 5, thus defining the research scope of work. This action helped define the ultimate research and development Scope of Work. Appendix B contains the alternative analysis tables and screening criteria used by the Project Research Team.

The TerraLogic team in coordination with the CDOT study panel reviewed over 100 potential research variables for consideration. A simplistic qualitative criteria was used to rank each variable from 1 to 5 based on cost, revegetation benefit, intensity of study, implementation by CDOT and professional judgment. As a result the list of potential research variables was reduced down to 50.

The next step in the alternatives analysis was to have the TerraLogic team and the CDOT study panel rank the remaining 50 potential research variables based on the previously mentioned criteria. This ranking reduced the number of research variables from 50 to 12. The final ranking and selection of the research variables was performed by the TerraLogic team and the CDOT study panel. The top 12 variables were priority ranked based on the following criteria scoring of the following elements:

- Availability
- Cost
- Sustainability
- Proven within other locations
- Scientific validity
- Practicality
- Statewide application
- Resource consumption
- Research cost and schedule

As a result of the alternatives analysis and conversations with the CDOT study panel, the following research variables were selected for study:

- Construction revegetation quality control
- Topsoil stockpile management
- Forensic field studies
- Revegetation survey of CDOT construction project engineers
- Revegetation cost analysis

## 2.4 Field Testing and Methodology Plan (Task 3b)

The Field Testing and Methodology Plan (the Plan) contains the technical approaches that were used to collect field data for the project (Appendix C). The Plan was approved by the CDOT study panel. The methodologies for the CDOT Revegetation Survey of CDOT Construction project engineers and Revegetation Cost Analysis were not included in the Plan, since these actions were conceived later in the Project.

The research study approach utilized a combination of field observations, field soil sampling collection and testing, and vegetative identification strategies. A research study hypothesis was established for each research study element to aid in the development and execution of the Plan. The selected research tasks and associated hypothesis for the Project include the following:

- Salvage Soil Management- the potential for improved plant revegetation can be achieved if nutrient and organic amendment requirements and mycorrhizal populations of topsoil are known before revegetation.
- Construction Revegetation Quality Control- the CDOT revegetation process is not being completely followed especially at critical steps. Therefore, the lack of specification compliance is negatively affecting the rate, quality, and overall success of revegetation.
- Forensic Revegetation Analysis- improved revegetation will occur if contractors follow specifications and contract requirements based on historical evidence from past projects.
- Revegetation Survey of CDOT Construction Project Engineers– the majority of CDOT construction engineering representatives lack basic technical and process knowledge to successfully manage revegetation activities.
- Revegetation Cost Analysis- CDOT Engineering and Maintenance management have underestimated the cost and effort for project revegetation and resulting rework.

## 2.5 Construction Quality Control Observation Methodology (Task 4a)

It was identified and recognized during the Literature Search (Task 1), and confirmed in the final research variable selection process, that understanding the effectiveness of the CDOT revegetation process and specifications in the field are not well known. There is very little oversight given to prime contractors and their landscaping subcontractors at critical times in the revegetation process. There is limited knowledge about the revegetation process by many engineers, maintenance, and environmental representatives.

Based on the information gathered in Task 1 and Task 2, the working hypothesis is that the rate and quality of the revegetation process is being negatively impacted by a lack of specification compliance. If this hypothesis is true, significant amounts of resources, time, and money are being inefficiently used to vegetate project locations, and an unnecessary amount of environmental risk and liability is being managed by CDOT maintenance.

Quality control (QC) is a critical management element in any process-orientated activity. It is the fundamental component of continuous process improvement and quality outcomes. QC ensures product reliability, sustainability and maintenance to achieve high quality results. The QC process within the revegetation context would be to outline the CDOT process, identify quality actions (specifications) and identify sensitive or high risk elements. These verification elements are the most critical links in the process that need to be visually verified to ensure overall process quality.

A process-based QC approach was used on active construction sites that performed or were in the process of performing site revegetation actions. A formalized Construction Revegetation QC Checklist Tool (QC Checklist) was used by the TerraLogic team to evaluate and document field compliance with CDOT specifications.

The following is the process that was used by the TerraLogic team on performing and assessing the CDOT revegetation process on active construction sites:

1. Selection of Active Construction Projects - CDOT selected five active construction projects that involved one to two site visits for each site undergoing revegetation. The active construction sites selected were based on site availability, phase of the project, and location. The number of visits was based on the level and type of revegetation occurring at the site. The sites that were selected were based on construction project complexity and diversity, CDOT regions, revegetation challenges, and project willingness for participation in the QC process. Table 2a provides a summary of the active construction sites that were visited by the TerraLogic team.
2. QC Checklist Development – The QC Checklist was developed in Task 3 and was used as a tool to assess revegetation compliance to the CDOT revegetation process and specifications and to facilitate revegetation discussion during on site interviews. The QC Checklist contains control actions that are from CDOT specifications and QC verification points (Appendix C-1).
3. Site Visits to Construction Sites - There were one to two individual QC site visits performed by the TerraLogic team for each identified construction site listed on Table 2a. The team attempted to visit the site at critical times and stages in the revegetation process that are identified as verification points in the QC Checklist. These verification points include control action such as but not limited to seed selection, soil amendment addition, seeding application, mulch application, and plant growth monitoring, etc. During the field QC studies, soil samples from surface soils and/or salvaged topsoil piles were collected (see Section 2.6).
4. Results Compilation and Analysis - An Excel database was developed for all the construction projects visited during the field QC study. The database was reviewed and assessed for QC compliance, process gaps, and potential CDOT specifications or actions that provide limited or no value to the revegetation process.

5. Follow Up Construction QC Information and Survey - The CDOT Research team anticipated the need for the TerraLogic team to obtain additional information or documentation from the project engineer or contractor, after the field visits were complete. Additional site visits or informational requests were conducted on selected sites.
6. Project QC Documentation – The TerraLogic team completed QC field visit summaries that contained QC checklists, photo-documentation, and project notes. These summaries were provided to CDOT as site visits were completed by the TerraLogic team (see Appendix D).

As previously mentioned, there were five active construction sites visited and observed by the TerraLogic team members. There were other construction sites throughout the state of Colorado that could have been visited and observed; however, due to access, travel distance, and project budget only five sites could be observed. Recognizing this small number of field observations in on site conversations with CDOT representatives, the Project Research team believed the conclusion and recommendation outcomes presented in this report are representative of many field conditions on CDOT construction projects.

**Table 2a. Construction QC Revegetation Assessment Locations**

| Geographic Region | Location/CDOT Region | Rationale |
|---|---|---|
| Southern Urban Foothills | Region 2 | Complex design-build construction project ranging from foothills to plains environments; ongoing revegetation activities were occurring. |
| Eastern Plains | Region 4 | Long linear construction project in a dry eastern plains environment; on-going permanent and temporary revegetation activities occurring. |
| East Urban Metro | Region 1 | Urban environment with limited space for revegetation; project adjacent to another agency project with different revegetation requirements; limited ongoing revegetation activities were occurring. |
| Mountain Corridor | Region 3 | Permanent revegetation activities had already occurred on steep slopes along I-70; mountain environment with limited growing season challenged revegetation efforts. |
| Urban Corridor | Region 1 | Complex design-build construction project with multiple phases and large amounts of soil disruption. |

It is important to note that project confidentiality was observed in this report. Confidentiality of QC observations, specification non-compliances, and project names were agreed upon with regional representatives to promote research cooperation and site access.

## 2.6 Topsoil Management and Salvage Methodology (Task 4b)

The scraping and salvaging of topsoil prior to construction is an important factor in successful revegetation. Topsoil that is salvaged and stockpiled provides the necessary soil conditions such as organic matter, nutrients, and native seed to promote successful revegetation. The objective of the topsoil salvage testing in Task 4 was to determine if proper and improved topsoil salvaging techniques can be used to decrease total revegetation costs and increase soil conditions to enhance revegetation success.

The TerraLogic team visited construction sites during the Field Revegetation QC Assessments to collect topsoil samples for laboratory analysis and evaluate topsoil salvage techniques. At selected construction sites the TerraLogic team collected samples that represent the no salvage, uniform salvage, Natural Resource Conservation Service (NRCS) salvage, and field verified salvage methodologies according to the Plan. The following soil collection and testing strategies are identified in Appendix C:

- No salvage alternative sample
- Uniform topsoil salvage sample
- Natural resource conservation service salvage sample
- Field verified salvage sample

Once the appropriate soil samples were collected, the samples were delivered to the qualified laboratory for analysis. Soil samples were analyzed for the physical and chemical parameters as defined in Appendix C.

### *Data Management and Analysis*

The goal of the soil testing and laboratory analysis was to identify soils that have chemical characteristics that were not conducive to vegetation success. The analytical testing and field data were reviewed to determine if improved, salvaged, stockpiled soils methods could be used to promote more efficient and successful revegetation. The data was reviewed to determine the best topsoil salvage methods that would be most likely to increase vegetation success, if followed prior to start of construction.

### *Seed Viability Testing*

Seed samples from two active construction sites were obtained for viability testing. Samples were sent to the North Dakota State University Seed Testing Laboratory for germination analysis (AOSA, 2014) according to the Association of Official Seed Analysts (AOSA). A grab sample from an available seed bag was obtained and delivered to the seed testing laboratory. Germination percentage of the seeds tested was provided for germinated, dormant, and hard seeds by species.

The data collected during the Construction Quality Control Observations Task that included field QC observations, soil sampling and seed viability testing is provided in Appendix E.

## 2.7 “Forensic” Revegetation Analysis Methodology

The objective of the forensic revegetation analysis was to determine the processes and crucial growth variables that improved revegetation success on former construction sites. Vegetation identification, diversity, and soil analysis among other factors were conducted to determine revegetation success at sites that were known to have followed CDOT specifications. Revegetation success was compared against undisturbed reference areas from similar and adjacent geographic and ecological areas. Construction methodology and seed mix design were evaluated to identify techniques that improved total revegetation success.

Previously vegetated sites were visited and data collected regarding topsoil characteristics, vegetative cover and composition, site topographic position and orientation, and hydrology. This data was analyzed and interpreted to determine whether or not sites have been revegetated successfully. Revegetation success was defined as a system that had greater than 70 percent native vegetation cover and had native vegetation cover that matched the local ecological vegetation community. To determine overall revegetation success the following items were evaluated and compared to the local site reference areas:

- Canopy cover
- Overall health
- Native plant abundance
- Ecological continuity

Table 2b contains the locations that were selected by the CDOT Technical Lead and were field evaluated by the TerraLogic team. These sites were selected because of their location, ecozone, complexity, past compliance to CDOT specifications, and site access.

**Table 2b. Projects for the Forensic Revegetation Analysis**

| Project | Location/CDOT Region | Geographic Region | Rationale |
|---|---|---|---|
| US-40 Berthoud Pass | Empire/Region 1 | Mountain | Complex and innovative revegetation strategies used in high altitude conditions. |
| US-50 | Grand Junction/Region 3 | West Slope | High salinity soils and drought conditions were revegetation challenges. |
| US-285 (Phase II) | Conifer/Region 1 | Foothill | Good soils and adequate rainfall provided optimal revegetation conditions |
| I-25 TREX (I-25 and University) | Denver/Region 1 | Urban | Urban environment with concentrated storm water and high applications of deicing agents challenged successful revegetation. |
| North Powers Boulevard Extension | Colorado Springs/Region 2 | Front Range/Non Developed | Newly constructed road base but road not completed. Revegetation is less than one year old. |

As previously mentioned, there were five active forensic sites that were visited and observed by the Project Research team members. There were other potential forensic survey sites throughout the state of Colorado that could have been visited and observed; however, due to access, traveling distance and project budget only five sites could be assessed. Recognizing this small number of potential observations, measurements, and conversations with CDOT representatives, the Research team believes the conclusions and recommendations are representative of many post-construction field conditions for former CDOT construction projects that followed CDOT specifications.

### *2.7.1 General Site Conditions*

At each forensic survey site the TerraLogic team and CDOT representatives evaluated the general site conditions and revegetation success based on, but not limited to, the following elements that were used to assist in the data interpretations and comparisons between reference sites and between former construction sites:

- Revegetation history
- Specifications
- Seed mix and percentage observed and measured
- Existence and extent of noxious weeds
- Topographic position
- Hydrological characteristics (drainage, run-on/run-off)
- Ecological habitat continuity
- Roadway design elements
- GPS location
- Elevation
- Slope

### *2.7.2 Vegetative Characteristics*

At each individual forensic survey site, vegetative cover and composition were assessed using line-point intercept transects, as described by the United States Department of Agriculture (Appendix F), throughout a revegetated area and at local representative locations in the adjacent off-ROW (reference areas). Specific vegetative survey sites were selected in the field by the TerraLogic team members based on field conditions, revegetation density, vegetation type, and previous topsoil treatments.

Vegetation was identified to the species level where possible. Each transect was 100 feet in length, with data collected every 10 feet. Qualitative characteristics of identified dominant vegetative species were recorded on data sheets for each former construction site. These characteristics included notes on phenology, evidence of grazing or herbivory, overall vegetative, native plant abundance, ecological continuity, and an overall qualitative vegetative rating.

### *2.7.3 Soil Characteristics*

At each vegetative transects surface soil conditions were visual evaluated and described by a soil scientist using a small excavated soil pit. The top two identified soil horizons were described based on the USDA-NRCS field protocols (Schoeneberger, 2012). Soil samples were collected from soil selected profiles. Collected soil samples were analyzed for pH and electrical conductivity (EC).

### *2.7.4 Data Evaluation*

All forensic data was compiled in an Excel spreadsheet database (Appendix G). Data was reviewed based on site specific conditions, field data collected, historical revegetation practices, and current vegetative states. The team did not review weather data trends during the revegetation process, but recognizes that such environmental factors are factors in revegetation success or failure, potentially limiting the conclusions drawn from such forensic analysis. Maintenance information such as mowing frequency, herbicide treatments, and chemical deicing applications were obtained from the CDOT maintenance SAP database to identify potential impacts to revegetation.

## 2.8 Revegetation Survey of CDOT Construction Project Engineers

The CDOT Research team with support from the TerraLogic team developed 23 survey questions that were distributed to CDOT construction engineers involved with highway design and construction management (Appendix H). The survey was sent to a broad population of engineers to obtain an unbiased sampling of the CDOT engineering population. Google Forms was the primary too used by CDOT to disseminate the questions and compile the survey results. All responses were kept entirely anonymous in an effort to encourage honest engagement.

The goal of the survey was to test the level of revegetation process understanding by CDOT engineers and how widespread various revegetation trends are in CDOT. This information allowed the TerraLogic team and the CDOT study panel the opportunity to assess the need for revegetation training and future research; and to identify areas of concern.

## 2.9 Revegetation Costs Methodology

The financial cost to CDOT maintenance for revegetation failure is assumed to be high. It is possible that CDOT is keeping the SCP open for an extended period of a time in order to achieve 70 percent-vegetative cover relative to pre-construction conditions. This 70 percent-vegetative cover relative to pre-construction conditions is required by CDPHE for SCP deactivation. This extended amount of time could be based on inadequate soil amendments and preparation, poor seeding technique, contractor compliance to specifications, and other factors as discussed in Section 3.

A cost analysis was performed for three revegetation scenarios. The first was a best case-worst case project cost comparison associated with revegetation rework costs; maintenance costs for TREX and I-25 from Lincoln Avenue to Lone Tree (Douglas County) were reviewed and compared. The second cost analysis involved evaluating the long term revegetation costs incurred by CDOT maintenance for nine recently closed out SCP projects. A range and mean of monthly costs for projects with recently closed (deactivated) SCPs was attempted for at least three years of maintenance activity. The projects were from various CDOT regions with differing complexity, size, and cost. The data was collected using the CDOT SAP system that keys on specific activity codes and costs within a large maintenance database. The third analysis involved actual CDOT maintenance costs, as compiled by CDOT Region 1, to address erosion control and revegetation deficiencies to obtain SCP deactivation and site stabilization. Twelve projects with open and deactivated SCPs were compiled, and accumulated non-project costs were summarized. Dates for project acceptance, SCP effective date, SCP deactivation date, duration for stabilization, and costs were obtained from Region 1. This information was to provide an indication on the costs being incurred by CDOT maintenance for the construction projects not doing erosion control and revegetation correctly the first time.

# 3.0 RESULTS AND DISCUSSION

The research results and discussion elements presented were the result of field observations, documentation reviews, interviews and communication with CDOT construction project engineers, RWPCMs, and prime and subcontractor representatives. The data collected was evaluated based on the research study's goals, objectives, and working hypotheses. A concise overview of the research results and technical discussion is provided for each step within the research project approach. This discussion established the basis for the research project's conclusions and recommendations in Section 4.0.

## 3.1 Revegetation Interviews and CDOT Specification Critique

Successful revegetation and site stabilization is a common challenge facing all CDOT regions and adjacent state DOTs. Weather conditions, contractor specification compliance, seeding windows, and the understanding of the revegetation process are all common challenges. The use of high risk contactors requires additional monitoring that impacts available resources. There is a consistent opinion within CDOT that poor communication between maintenance and engineering personnel leads to revegetation problems such as herbicide application and mowing. This section discusses these and other process and programmatic issues affecting revegetation success.

A critique of CDOT specifications and revegetation process is provided by TerraLogic team member, Western States Reclamation. The critique concentrates on problems with top soil management, soil preparation, soil amendments, seed mixes, and qualified contractors.

### *3.1.1 Revegetation Interviews*

The TerraLogic team contacted 18 CDOT employees, and seven regional state DOT revegetation-landscaping professionals. There were some consistent points of view associated with construction revegetation challenges and successes. The following summarizes the main areas of discussion that were generally consistent among the interviewed professionals.

### *Regional State DOT Landscaping Professionals*

DOT landscape professionals from states other than Colorado were contacted by the TerraLogic team. These references were selected due to the similar climate, soil types, and environmental conditions to the state of Colorado. The state DOT's contacted were New Mexico, Nebraska, Kansas, Utah, and Wyoming. The responses revealed the following consistent challenges and themes:

- Most DOTs attributed some challenges of revegetation to drought conditions; none of them were a proponent of irrigation due to high costs and poor results.
- DOTs recognized the need for additional resources to oversee contractors during critical times such as seed planting and plant establishment. Overall revegetation specification compliance is a consistent problem with contractors' performance.
- Internal certification or pre-qualification of revegetation contractors would be advantageous to revegetation success.
- Native plants take longer to establish than non-natives, which adds to the long term project cost and stormwater permit coverage duration.
- It is difficult to coordinate with design engineers in planning revegetation strategies that include site re-grading, slope steepness, and plant establishment.
- There is a challenge in specifying revegetation expectations to contractors before and during construction.
- Poor-performing revegetation contractors are known and are closely monitored whenever possible in the field; it is difficult not to use them due to low-bid competition and a lack of prequalification requirements.
- It is hard to make contractors responsible for complete and successful site revegetation due to contracting constraints associated with time necessary to establish revegetation versus completing the overall project construction project.
- No DOTs use soil testing before construction to assess amendment requirements but recognize the need for soil testing; some are uncertain about the soil testing methodology and data application.
- DOTs recognize a need for better communication with herbicide sprayers who impact revegetation site growth within the ROW.

### *CDOT Landscape Architects and RWPCMs*

CDOT RWPCMs often review project sites undergoing revegetation more often that landscape architects, since they need to monitor and document erosion control conditions as a SCP requirement. The level of revegetation understanding by most CDOT RWPQM interviewed is limited; however, their insight and comments are important and reflect common concerns and observations:

- Most interviewed CDOT professionals think that the contractors are not consistently following CDOT "Green Book" specifications.
- Most CDOT representatives mentioned the lack of available resources for effectively monitoring contractors during revegetation.

- There is no identified responsible CDOT representative in the field to coordinate, oversee, and monitor the contractor during actual soil preparation, seeding, and vegetative establishment before transferring the project to CDOT maintenance.
- There needs to be revegetation training for the CDOT project engineers and RWPCMs.
- The seed mixture is perhaps too broad and not project-site specific; using an ecozone selection approach could improve vegetation establishment.
- There are inconsistencies on how percent-vegetative cover is calculated before and after construction to achieve 70 percent-vegetative cover.
- There could be more detailed site-specific landscape design plans developed within the SWMP that should be developed by the contractor or by CDOT.
- A contractor escrow fund should be considered to ensure an expected level of revegetation occurs before their complete departure from the project.
- Revegetation is an afterthought by contractors and some project engineers who are anxious to move onto the next project.

### *3.1.2 CDOT Specification and Process Critique*

The CDOT Standard Specifications for Road and Bridge Construction 2011 ("Green Book") covers basic and conventional revegetation practices for Colorado contract work that is awarded by CDOT. Based on the TerraLogic team's revegetation experience, it is recognized that more detailed information is typically provided beyond the Green Book on project plan sheets, project special provisions and on CDOT request for proposal (RFP) scopes of work. This CDOT approach appears to be sufficient as a project foundation and provides CDOT the opportunity to custom design the revegetation scope of work based on site conditions. Sections of the Green Book relating to revegetation practices were reviewed and examined by the TerraLogic team. The following is a critique of CDOT specifications and several recommendations for potential changes:

#### ***Specification Section 207 Topsoil***

Section 207 references the handling and placing of topsoil material on CDOT projects. Soil is a critical element in the establishment of plants and this section would benefit from additional language regarding the methodology for proper topsoil identification, salvage, storage, and placement. A list of suggested project specifications and design guideline changes or modifications is included, based on the TerraLogic team's professional judgment:

- Currently there are no CDOT specifications or standards for identifying suitable seedbed quality material (topsoil) prior to initiation of construction activities. The practice of using soil surveys to identify the quality and quantity of topsoil for use in revegetation has been utilized by the mining industry for nearly 40 years. The costs of conducting a pre-disturbance soil survey and topsoil management plan will be offset by adding correct soil amendments to only soil materials which potentially lack favorable seedbed quality material. Management of topsoil resources will reduce failed revegetation maintenance and monitoring costs. Pre-construction soil analysis and surveys are necessary because often CDOT disturbances take place in areas of previously disturbed right of way conditions, which makes the NRCS soil survey data of minimal use.

- Topsoil Section 207 would benefit from further discussion on the importance of maintaining segregated topsoil stockpiles throughout construction. Co-mingling of topsoil with other non-suitable onsite soils should be avoided.
- Topsoil Section 207 could benefit from language restricting topsoil salvage in unfavorable conditions, such as soil moisture conditions that are too dry or too wet. If topsoil is salvaged in unfavorable conditions it could lead to permanently damaging beneficial soil structures and composition.
- The identification and use of suitable subsoil materials should be incorporated into the specifications and/or a landscape design plan. Utilizing quality subsoil could increase project success and reduce overall project costs. Quality subsoil conditions would have to be identified in the field by a soil scientist and confirmed with soil testing and analysis.
- Ensure that the stripping and stockpiling of available topsoil is executed properly by having onsite inspections by trained personnel. Additional inspections would have to be made throughout the duration of the project to make sure salvaged soils are being stored properly.
- Destroying soil stockpiles during earthwork activities is not acceptable and should be enforced in the project specifications. If available topsoil is identified, but is not properly salvaged or stored according to specification, the contractor should be responsible for importing quality topsoil or adding additional amendments without cost to CDOT. In order for this system to work, a topsoil salvaging, stockpiling, and placement plan should be planned and designed with a landscape design plan in the SWMP or other enforcement document.
- Proper equipment and tools should be used for topsoil placement. Heavy equipment can cause soil compaction, which hinders root growth and plant development.

### *Specification Section 212 Seeding, Fertilizer Soil Conditioner and Sodding*

Overall, these specifications cover basic regional revegetation practices and include discussions on timing, materials and standard rates. Additional revegetation information and design is typically provided on project plans such as amendment rates and project specific seed mixes.

Listed below are topics that should be considered for incorporation into landscape design plans and/or specification section 212:

- The use of qualified contractors to perform revegetation would increase project success. The specifications have language directed towards the use of proper revegetation equipment, but the use of qualified personnel trained on proper revegetation equipment and methods are also critical factors in project success that are not directly addressed.
- Amendment type and associated application methods should be considered when recommendations are identified by a soil scientist and or CDOT landscape architect. In some cases, a surface application may be advantageous in contrast to the specified incorporation depth of 4 inches or 6 inches. Boilerplate soil amendment recommendations within the SWMP should be avoided by the designer, since this could lead to over or under application of amendments.
- The use of soils amendments needs to be based on soils test results including organic matter content, nitrogen-phosphorous-potassium (N-P-K), electrical conductivity, soluble ions, pH, Sodium Absorption Ratio (SAR), and calcium carbonate percent.

- It is very difficult to get standard agricultural equipment on 2:1 slopes to drill seed. A 2.5:1 slope should be the maximum slope for drill seeding and straw mulching.
- Soil preparation as a required two-step process for tillage would improve seedbed specifications. Most times ripping the soil surface only once is not adequate, and contractors often bid to do it just once. As a pay line item, soil ripping per acre, per pass might get better soil preparation and overall revegetation success.
- Current seed plans appear to be based on regional vegetation zones or broad ecosystem communities. This practice may be too general to determine the appropriate seed mixture that should be utilized for site-specific vegetation communities.
- A review of several seed mixes indicates that there has not been consideration for balancing the drill seed rate to an average of 50 to 60 seeds per square foot, which is an accepted standard in the western United States
- Distributing too few or too many seeds can be detrimental to plant establishment. An overabundance of seeds per square foot can lead to intense competition for water and nutrients that may not be available in the soil. This could negatively affect vegetation diversity or lead to eventual die off of the vegetation community.

### *Specification 213-Mulching*

The CDOT mulching specification section covers basic mulching materials, methods and practices. This section appears to provide adequate guidelines for contractors to follow; however, a few additions and corrections could make this section better. Inspection of material quantity and quality is critical when it comes to achieving proper coverage during mulching operations. Enforcement of crimping depth, straw/hay mulch length, and overall quality of materials used would greatly increase the effectiveness of mulching on revegetation projects.

There are some adjustments to the specifications that could be made that would help improve the current specifications and provide a higher potential for greater project success. The addition of science-driven project special provisions and plans derived from onsite sampling and observation is critical to revegetation success and cost effectiveness.

## 3.2 Construction Revegetation QC Assessment

A process QC approach was used to observe and evaluate the application and compliance to specific CDOT revegetation specifications. This revegetation assessment was performed to test the hypothesis that the CDOT revegetation process is not being completely followed especially at critical steps; therefore, the lack of specification compliance is negatively affecting the rate, quality and overall success of revegetation. Compliance and understanding of CDOT specifications by contractors and CDOT field representatives was identified as a major success issue early in the project. Contractor non-compliance to CDOT specifications was a common observation during the QC assessment. Many times changes were instituted unilaterally by the contractor without project engineer knowledge or approval. It appears that project engineers and maintenance staff do not use landscape architects or qualified individuals to aid in revegetation-based decision making in the field.

Salvaged topsoil is an important component to site revegetation since it contains soil structure, organic matter, microbial biomass, and native seed material. CDOT specifications are very specific about removing and stockpiling topsoil for future revegetation use. Soil samples were collected at four construction projects during the QC visits to test the hypothesis that the potential for improve plant revegetation can be achieved if nutrient and organic amendment concentrations of topsoil are known before revegetation.

Five active construction projects were visited and assessed using the QC Checklist. The QC Checklist documented specific revegetation activities and was also a tool used to facilitate discussion among project engineers, TECS, and landscape subcontractors. Active construction sites within the following areas and regions were visited by the TerraLogic team:

- Southern Urban Foothills (Region 2)
- Eastern Plains  (Region 4)
- Urban Metropolitan Area (Region 1)
- Mountain Corridor (Region 3)
- Urban Corridor (Region 1)

### *3.2.1 Southern Urban Foothills (Region 2)*

The TerraLogic team visited an active design-build project south of the Denver Metropolitan Area three times. The following highlights the main observations made during these field visits. The completed Field Visit Observation Summary Report can be reference in Appendix D-1:

- Soil amendments were not consistently used on the project, which is a CDOT specification requirement. The areas that were amended with compost had the best vegetative growth and less soil compaction. It is questionable that some areas were tilled, de-compacted, or scarified before planting due to soil surface hardness. The project engineer was not aware of, nor asked about any specification change to allow this non-soil preparation modification.
- Straw mulch was supposed to be applied all previously disturbed areas; however, tackier was not added to the straw mulch which is a CDOT specification requirement. As a result, the straw mulch that was previously applied was being blown away, which resulted in large areas of exposed soil.
- The RWPCM did not perform the pre-construction percent-vegetative cover and had the understanding that noxious/non-native weeds count as percent cover when performing the measurement. This appears to be contrary to the existing CDOT protocol.
- There was a lack of time for the RWPCM to watch and review contractors during seeding and other critical revegetation times. The RWPCM mentioned that they have not beenadequately trained to review and assess revegetation actions, nor do they feel they have the time to do so.

- An independent construction management contactor was reviewing contractor conformance to CDOT specifications; however, it appears that compliance to revegetation specifications such as the soil amendments and tackifier issues already mentioned were not being follow or documented.
- It was noted that seed mix was being stored in the drill seed applicator's metal bin (see Figure 1). The viability of this stored seed is questionable since seed viability can be impacted by temperature extremes. It should have been stored under controlled conditions that avoid temperature extremes.
- Seed mix onsite had different plant species and seeding rate than specified in the SWMP provided to the TerraLogic team for review.
- Seed mix was applied at a drill seeded rate of 177 PLS pounds per acre (lb./acre). This is well over the optimal seeding rate of 60 PLS lb./acre used in standard reclamation practice.
- There was no verification or documentation to substantiate that the drill seeders had been calibrated prior to or during the project.
- Two seed drills were inspected during the site investigation. One of the seed drills was placing the seed behind the openers and the press wheels and did not appear to be applying adequate downforce. This seeder did not have the needed depth bands on the openers (specification 212.07). The second seed drill reviewed had proper seed placement and depth bands.

**Figure 1. Drill seeder storing seed**

- Seeding was performed outside of appropriate seeding windows (September 15 to ground freeze and Spring Thaw to June 1) as per CDOT specification 212.03. It is probable that the temporarily established vegetation started from summer planting will not survive winter conditions.

### ***Salvaged Topsoil Management***

Topsoil was stockpiled according to CDOT specification 207.03. The following summarizes the topsoil management observations:

- A maximum of 4 inches of topsoil were stockpiled throughout the project area.
- Some mixing of topsoil with subsoil was occurring (Figure 2)
- No BMPs were observed at the topsoil pile to protect the soil from wind and or water erosion and transport (Figure 3).
- Topsoil piles were not clearly identified with signage. Topsoil had been stockpiled in the same area since October 2013.

**Figure 2. Topsoil mixed with subsoil.**

**Figure 3. No wind or water erosion control on topsoil piles.**

- Topsoil spreading was being completed on portions of the disturbed ROW (Figure 4). It was noticed that prior to spreading the subsoil the surface was not prepared for topsoil placement. A clear and definite discontinuity among soil layers was being established which could decrease revegetation success. This potential discontinuity between soil layers could result in poor water movement between soil layers.

**Figure 4. Topsoil spreading in progress.**

### *3.2.2 Eastern Plains (Region 4)*

A six mile construction project located on the eastern plains was visited twice by the TerraLogic team. The following highlights the main observations made during these field visits. The completed Field Visit Observation Summary Report can be referenced in Appendix D-2:

- Organic amendment with N-P-K of 6-1-3 and humates were called out on the plans. All seeding prior to September 2013 received Biosol 7-2-1 and humates; however, after September 2013 the seeded areas received Sustane 8-2-4 and humates. The contractor inspector stated there were issues with pricing and availability, which is why the contractor switched amendments.
- The contract inspector monitored drill calibration, but did not provide written documentation. The verification and documentation of the drill depth and seed application are critical factors towards successful revegetation and specification compliance.
- One steep area within the project area was hydroseeded and hydromulched, and then erosion control blanketed. It was not documented who approved of this modified seeding and mulching approach.

- As stated by the landscape subcontractor, the CDOT project engineer directed the landscape contractor to temporarily stabilize areas via seeding and mulching without using soil amendments; as a result, many of these areas ultimately become permanent revegetation areas without the soil amendments. This supposedly resulted in spotty revegetation success. Amendments could be added to the soil (in this case, imported soil) regardless if it is going to be associated with temporary or permanent revegetation.
- The landscape contractor felt CDOT seeding windows made sense but there needed to be some flexibility, depending on site conditions, where June 1 was the latest that the project could seed according to specifications. The project may ask the project engineer to extend the seeding period. The project engineer should not make this decision without consulting a CDOT landscaping architect or qualified CDOT representative.
- It was mentioned that CDOT maintenance herbicide applications are affecting revegetation success. CDOT needs better weed control along the ROW near revegetation areas. A well-orchestrated Integrated Noxious Weed Management Plan (IWMP) under the coordination of a CDOT landscape architect or qualified CDOT representative is needed to ensure new vegetation is not being impacted and, at the same time, not out competed by noxious and invasive weeds. A project specific IWMP should be part of a more detailed landscape design plan.
- The TECS could not find the pre-construction percent-vegetative cover data and was not aware of who performed the measurements. It was assumed by the TECS that this information resides with the CDOT project engineer; however, the documentation was not in the SWMP.

#### ***Salvaged Soil Management***

Topsoil was “windrowed” via placement into small berms and not stockpiled as per CDOT specification 207.03. The topsoil was scraped aside into linear piles along the interstate access road. No topsoil horizon-depth measurement was taken prior to grading. Observation showed no real organic matter/topsoil horizon present within the windrowed berms.

### *3.2.3 Urban Metropolitan Area (Region 1)*

The project, that included both roadway improvements and bridge construction, was located within the Denver Metropolitan Area. The project was adjacent to, and associated with, another transportation agency project. The project was characterized by ROW space constraints within an urbanized area with little existing ROW vegetation.

The completed Field Visit Observation Summary Report can be reference in Appendix D-3. The following highlights the main observations made during two field visits:

- No compost was added to the topsoil as required by CDOT specification. The project engineer was not aware of the requirement for compost nor the prime contractor’s unilateral decision to eliminate compost application.

- Two transportation agencies are in the process of construction. These sites were immediately adjacent to each other. There was confusion about who was responsible for revegetation and what specifications to follow. There was a lack of CDOT project engineer and contractor leadership on solving this issue. A project-specific landscape design plan would have been a helpful tool to resolve this revegetation responsibility gap.
- The revegetation subcontractor stated that monthly revegetation inspections occur to check on progress; however, based on field observation and the amount of exposed soil, routine monitoring was questionable. Routine revegetation monitoring by the subcontractor and/or CDOT would have been important to measure revegetation success and to identify problems early in the process.
- Pre-construction percent-vegetative cover was not quantitatively measured as required by CDOT. Photos, apparently shot from a moving vehicle, were used for pre-construction documentation (Figure 5). Vegetative cover greater than, or equal to, 70 percent from pre-construction levels will be impossible to correctly document to CDOT and/or to CDPHE.

**Figure 5. Example of pre-construction percent vegetation photo for documentation**

- High soil compaction conditions were noted during the field visit. It appeared that the project failed to comply with CDOT specification 212.06 for soil preparation. Figure 6 shows poor revegetation success and exposed soils due to soil compaction and poor seeding installation.

**Figure 6. Limited revegetation success due to soil compaction and seed installation**

- It was mentioned by the prime contractor that most revegetation efforts would be conducted between late spring and early fall, which would have been outside of the CDOT specification seeding window.
- There was no real metric or performance standard that was expected to be achieved by the contactor in order for CDOT to sign off and approve the revegetation conditions; only a visual observation was to be used for acceptance. This observation is contrary to the CDOT Water Quality Permit Transfer to Maintenance Punchlist requirements (Appendix I).
- A CDOT landscape architect should be needed at the maintenance punchlist sign off stage to support the CDOT maintenance representative and ensure revegetation is progressing and has been established in an expected manner.
- The CDOT project engineer and RWPCM did not feel comfortable making revegetation assessments and recommendations. There was an agreement that revegetation training was needed to better monitor and evaluate revegetation success over time.
- No communication between the CDOT project engineer and the CDOT landscape architect had occurred or was expected to occur during future seeding or soil preparation.
- No discussions occurred during the environmental pre-construction meeting about revegetation performance expectations. It was important for the CDOT project engineer and landscape architect to discuss revegetation expectations early in the process with the prime contractor and their landscaping subcontractor.
- The prime contractor felt that if CDOT wants a quality revegetation job on future projects, the expectations need to be identified early in the RFP to so accurate revegetation costs can be developed.

***Salvaged Topsoil Management***

- Topsoil depth was based on visual observation. It was mentioned by the TECS that some grading occurred at night; therefore and accuracy of topsoil depth removed for stockpiling was questionable.
- No erosion control from stormwater and wind was instituted by the contractor for the salvaged topsoil pile
- Topsoil was stockpiled and samples were collected along with background soil samples.
- Topsoil stockpile had Listed B noxious weeds present on the pile. The noxious weeds were going to seed and in need of eradication (Figure 7). An IWMP contained with a landscape design plan would have been helpful to the TECS.


06.06.2014

**Figure 7. Topsoil stockpile containing noxious weeds and no BMPs.**

### *3.2.4 Mountain Corridor (Region 3)*

The TerraLogic team conducted a site visit for seeding operations in May 2014 at an active CDOT construction Project located along the I-70 West Mountain Corridor at an elevation of 6,600 feet above sea level. The TerraLogic team discussed the project revegetation progress and the QC Checklist with the CDOT Contracted Management-project engineer, RWPCM, landscape contractor, and the TECS. The following highlights the main observations made during this field visit. The completed Field Visit Observation Summary Report can be reference in Appendix D-5:

- The seeding methodology was changed from drill seeding to broadcast seeding, raking, and hydromulch. The change was requested due to a large proportion of steep (>2:1) slopes on the project site.
- The change in seeding specifications was authorized by the Contract Management-project engineer. Seeding rates were increased 1.5 times the normal drill seeding rate for the broadcast seeding. It was noted during the site inspection that multiple areas could have been drill seeded.
- The project site was seeded and hydromulched around November 15, 2013 (within the seeding window), little if any remaining hydromulch was observed on the site during the site visit (Figure 8).

**Figure 8. Soil surface with limited hydromulch remaining.**

- A high level of soil compaction was observed in the top 3 to 4 inches of the soil surface. Figure 9 shows evidence of the compaction with most of the staples for the erosion-control blanket not placed all the way to depth or bent.

**Figure 9. Blanket staples not installed completely - likely due to high soil compaction.**

- The landscape contractor did not understand the specification for soil conditioning and fertilizer requirements; and therefore did not apply the specified products.
- A single vegetation transect was meant to be representative of 19 acres of previously disturbed area and was used to establish pre-construction percent-vegetative cover conditions. During the site inspection the TerraLogic team noticed multiple ecozones within the ROW that likely had varying degrees of vegetative cover. It is very probable that one transect at one location would not be representative of the entire project area.
- The seed mix was reviewed and appeared appropriate for the site. The seeding rate was calculated at 212 PLS per square foot, which is extremely high, and could cause competition during establishment. This high rate of seeding probably resulted in excessive financial spending for seed mixes.

### *Salvage Topsoil Management*

According to the TECS, topsoil was salvaged and moved offsite due to limited storage room within the construction ROW. The offsite topsoil stockpiles were reviewed and, based on visual evidence, it was determined that the stockpiles were comprised of large rocks, electrical wiring, sheet metal, and large woody debris (Figure 10). This condition is not in conformance to CDOT specification 207.02. No samples were collected for testing.

**Figure 10. Compromised offsite topsoil stockpile.**

### *3.2.5 Urban Corridor (Region 1)*

The TerraLogic team conducted a construction revegetation QC observation visit on an active construction site representative on an Urban Corridor Project during September, 2014. During the site visit, soil samples were obtained from a salvaged topsoil pile, a background soil sample, and a NRCS soil sample. The Urban Corridor Project was a design-build project and the SCP was held by the prime contractor. It appeared that the TECS was also the landscape contractor.

The completed Field Visit Observation Summary Report was completed during the visit (see Appendix D-5). The following are the site observation results and discussion:

- The subcontractor was referencing CDOT specifications 214.04, in which the first paragraph states: "throughout the Landscape Establishment Period, the contractor shall maintain all plant material and *seeded areas* in a healthy and vigorous growing condition and ensure the successful establishment of vegetation. Landscape architect to determine acceptability of plant material."
- This specification lacks specific detail in regards to landscaping and seeding establishment. It is assumed that this specification relates to non-irrigated vegetation development (i.e. revegetation). The terminology of "healthy and vigorous growing condition and ensure the successful establishment of vegetation" was not well defined.

- The Notice of Landscape Completion documentation had not been observed during any construction revegetation QC site visits. It was not clear if this revegetation compliance activity was actually performed at this and other sites. In addition, there was no mention or documentation reviewed that indicated that the contractor, CDOT project engineer and CDOT landscape architect determined acceptability of plant material, which could be interpreted to include plant seeding. The insertion of "seeded areas" into the specification 214.04 makes the requirements for un-irrigated areas confusing and perhaps not applicable to large scale revegetation.
- There was a lot of confusion about the proper seed mix for the project. Five different seed mixes were proposed by a landscaping consulting firm. Apparently the proper seed mix was not detailed by CDOT in the RFP and there was no CDOT regional support on this issue. Apparently the landscape consultant made the determination for the final seed mix without CDOT concurrence.
- Compost and other soil amendments were not added to existing topsoil used for revegetation. This decision was not based on previous soil chemical data but apparently made by the prime contractor management to ignore amendment specification requirements established and/or approved by CDOT for the project scope of work. This action caught the attention of the CDOT project coordinator and the contractor QA representative.
- The top six inches of topsoil was removed, collected and stockpiled within piles or berms at various locations along the project area. No erosion-control BMPs were used at the stockpile location sampled for this visit.
- Herbicide on topsoil was not used but it was in the CDOT Project RFP. According to the landscape contractor, there appeared to be a potential disconnect between the CDOT specifications and RFP requirements on this herbicide issue. CDOT landscape architects should develop or at least review revegetation language in RFPs before finalization.
- Seeding was performed outside the seeding window as required by CDOT specification 212.03. Seeding occurred into late June, 2014 time period (after the June 1 period) and started the first week of August 2014 (before the September 15 period).
- It was mentioned by the TECS that revegetation areas were monitored after seeding; however, the action is not documented and is not performed on a routine schedule.
- If there is a revegetation problem identified by the landscape contractor, it is not clear if this was identified as a formal and documented corrective action requiring attention and action.
- Apparently a formalized landscape design plan was required in the RFP; however, no such plan was available for review.

### *3.2.6 Topsoil Characterization Overview*

Soil samples collected from the four construction revegetation QC site visits indicated that topsoil management can affect soil quality significantly. In three of the four sites where topsoil was salvaged, the soil electrical conductivity (EC) increased by at least two-fold between the undisturbed surface soil sample and the topsoil sample (Table 3a). The increase in soil EC was likely due to either mixing of greater EC subsoil with topsoil (Eastern Plains) or solubilizing $CaCO_3$ (Urban and Urban Corridor). No free $CaCO_3$ was observed in the soil matrix at the

Southern Foothills site, the only site without an increase in soil EC. This increase in EC could negatively impact plant germination and revegetation success if it exceeds specific plant salinity tolerances.

### Table 3a. Construction Revegetation QC – Soil Testing Results

**Southern Foothills**

| Salvage Technique | Depth | pH | EC | Saturation | Excess Lime Rating | Sol. Ca | Sol. Mg | Sol. Na | SAR | NO3-N | NH4-N | Inorganic N | Bray P-1 | Exch. K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | inches | S.U. | dS/m | % | -- | meq/L | | | -- | mg/kg | | | | |
| Uniform | 0-6 | 6.8 | 0.19 | 31 | None | 0.70 | 0.33 | 0.35 | 0.5 | 1.8 | 7.3 | 9.1 | 1.2 | 127 |
| Field | 0-14 | 6.7 | 0.24 | 31 | None | 1.05 | 0.50 | 0.30 | 0.3 | 3.6 | 7.1 | 10.7 | 1.3 | 114 |
| NRCS | 0-16 | 6.4 | 0.34 | 37 | None | 1.45 | 0.40 | 0.48 | 0.5 | 2.6 | 6.6 | 9.2 | 0.8 | 91 |
| No Salvage | 0-18 | 6.9 | 0.30 | 33 | None | 1.60 | 0.67 | 0.43 | 0.4 | 2.6 | 6.9 | 9.5 | 0.4 | 71 |
| Topsoil | Pile | 6.2 | 0.20 | 36 | None | 0.80 | 0.33 | 0.39 | 0.5 | 5.3 | 4.9 | 10.2 | 1.5 | 54 |

**Mountain Corridor**

| Salvage Technique | Depth | pH | EC | Saturation | Excess Lime Rating | Sol. Ca | Sol. Mg | Sol. Na | SAR | NO3-N | NH4-N | Inorganic N | M3 - P | Exch. K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | inches | S.U. | dS/m | % | -- | meq/L | | | -- | mg/kg | | | | |
| South | 0-4 | 8.00 | 0.37 | 40 | High | 4.40 | 1.25 | 0.22 | 0.1 | 4.3 | 1.7 | 6 | 25 | 240 |
| South | 4-12 | 8.00 | 0.33 | 39 | High | 3.90 | 13.00 | 0.22 | 0.1 | 2 | 2.3 | 5 | 16 | 123 |
| North Facing | 0-6 | 8.00 | 0.87 | 28 | High | 6.55 | 2.42 | 0.96 | 0.5 | 10.6 | 2.1 | 13 | 19 | 120 |

**Eastern Plains**

| Salvage Technique | Depth | pH | EC | Saturation | Excess Lime Rating | Sol. Ca | Sol. Mg | Sol. Na | SAR | NO3-N | NH4-N | Inorganic N | M3 - P | Exch. K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | inches | S.U. | dS/m | % | | meq/L | | | -- | mg/kg | | | | |
| Uniform | 0-6 | 6.6 | 0.17 | 30 | None | 0.55 | 0.33 | 0.39 | 0.6 | 2.9 | 2.0 | 4.9 | 34 | 213 |
| Imported | Sur | 7.6 | 1.55 | 28 | High | 7.90 | 3.17 | 4.35 | 1.9 | 26 | 2.5 | 29 | 48 | 181 |
| No Salvage | 0-18 | 7.7 | 0.37 | 30 | None | 2.50 | 0.92 | 0.26 | 0.2 | 3.2 | 2.6 | 5.8 | 59 | 192 |
| Topsoil | Berm | 7.4 | 0.42 | 29 | None | 1.75 | 1.17 | 0.61 | 0.5 | 14 | 3.5 | 18 | 110 | 140 |

**Urban**

| Salvage Technique | Depth | pH | EC | Saturation | Excess Lime Rating | Sol. Ca | Sol. Mg | Sol. Na | SAR | NO3-N | NH4-N | Inorganic N | Melich 3 P | Exch. K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | inches | S.U. | dS/m | % | -- | meq/L | | | -- | mg/kg | | | | |
| NRCS | 0-8 | 7.8 | 0.32 | 37 | Low | 2.00 | 0.30 | 0.52 | 0.5 | 2.2 | 0.7 | 2.9 | 22.0 | 135 |
| No Salvage | 0-18 | 8.0 | 0.36 | 33 | High | 1.60 | 0.50 | 1.87 | 1.9 | 2.1 | 0.7 | 2.8 | 14.0 | 90 |
| Topsoil | Pile | 7.5 | 3.23 | 36 | High | 19.50 | 5.25 | 10.43 | 3.0 | 21.7 | 0.9 | 22.6 | 32.0 | 155 |

**Urban Corridor**

| Salvage Technique | Depth | pH | EC | Saturation | Excess Lime Rating | Sol. Ca | Sol. Mg | Sol. Na | SAR | NO3-N | NH4-N | Inorganic N | M3 - P | Exch. K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | inches | S.U. | dS/m | % | -- | meq/L | | | -- | mg/kg | | | | |
| NRCS Comp 1 | 0-6 | 7.4 | 0.82 | 47 | High | 5.20 | 1.67 | 2.09 | 1.1 | 2.3 | 2.5 | 4.8 | 31 | 426 |
| NRCS Comp 2 | 0-6 | 7.4 | 0.86 | 45 | High | 5.45 | 1.75 | 2.22 | 1.2 | 4.2 | 2.3 | 6.5 | 32 | 417 |
| Background | 0-6 | 7.6 | 0.80 | 40 | High | 3.70 | 1.58 | 3.65 | 2.2 | 5.4 | 3.7 | 9.1 | 25 | 299 |
| Topsoil | Berm | 7.6 | 3.77 | 45 | High | 15.30 | 5.50 | 20.70 | 6.4 | 24.1 | 4.7 | 28.8 | 31 | 271 |

In the two urban areas reviewed, the soil within the topsoil piles had a six-fold increase in soil SAR relative to baseline soil conditions. Increases in soil SAR negatively impacts soil structure and water movement into and through the soil. In addition, an increase in SAR can increase soil crusting that can negatively impact plant establishment since the seedlings may have trouble pushing up through the surface crusts. The increase in soil SAR could be due to many factors but the two likely factors on a ROW include placing the topsoil pile too close to the active road surface and using of the topsoil material as a stormwater BMP. Both of these factors allow the topsoil to come in contact with road deicing agents, which likely increase soil salinity and SAR.

Soil fertility in the analyzed soil samples varied greatly between locations based on parent material and soil texture. In general, the existing soil fertility was adequate for revegetation success and the addition of fertilizer w not required for a majority of the sites (Mortvedt et al., 1996). It was therefore important that non top soil material not be mixed or added to the salvaged topsoil pile.

Soil tests were obtained from the Eastern Plains Site where topsoil was being imported due to concerns about the lack of suitable native topsoil and available fill. The soil tests revealed that the imported topsoil had significantly worse chemical and physical characteristics than other soils on the site. The soil EC and SAR ratings were all above levels that could negatively impact revegetation success. Soil organic material (OM) was less than 0.5 percent, which is not adequate to promote soil nutrient cycling or water holding capacity. The beneficial aspect of the imported material was that the soil texture (Sandy Loam) was slightly more favorable than the native topsoil (Loamy Sand) for revegetation success.

### *3.2.7 Seed Viability Testing Overview*

Based on the results of the seed germination testing, a large variance in germination percentage was observed between the seed samples collected from the Southern Urban Foothills (Region 2) and the Eastern Plains (Region 4) projects. In general the laboratory tested germination percentage was 10 and 17 percent less than shown on the seed tags (Tables 3b and 3c). Individual species showing an increase of 10 percent to a decrease of 84 percent at the Southern Urban Foothills site (Table 3b). At the Eastern Plains site seed germination percentage, by species, increased a maximum of 26 percent with a maximum decrease of 51 percent (Table 3c). These dramatic decreases in seed germination are indicative of poor seed management and handling by the contractor or the use of old seed. The seed viability testing was conducted on seed supplied by two separate, very reputable, seed suppliers.

**Table 3b. Southern Urban Foothills Seed Viability Testing Results**

| Seed Viability | | | | |
|---|---|---|---|---|
| **Species** | **Actual** | | **Seed Tag Germination** | **Percent Change** |
| | **Germination** | **Dormant** | | |
| Blanketflower | 88% | 0% | 80% | 10% |
| Little bluestem | 48% | 13% | 94% | -35% |
| Galleta | 81% | 8% | 95% | -6% |
| Junegrass | 78% | 0% | 92% | -15% |
| Blue grama | 49% | 18% | 85% | -21% |
| Sideoats grama | 57% | 2% | 94% | -37% |
| Green needlegrass | 18% | 77% | 93% | 2% |
| Prairie coneflower | 81% | 0% | 82% | -1% |
| Inland saltgrass | 3% | 85% | 97% | -9% |
| Oats | 15% | 0% | 95% | -84% |
| Western wheatgrass | 84% | 3% | 85% | 2% |
| Switchgrass | 91% | 3% | 97% | -3% |

Some seed tags obtained from the contractors showed that the seed was tested at least 365 days prior to use. Seed testing results are only good for one year. If the seed is beyond one year of testing, it does not mean the seed is not viable; however, it does indicate that a new germination test must be performed prior to the use to verify quality. The 365 days between seed tests assumes that the seed will be kept in appropriate storage conditions until it is planted.

During the construction revegetation QC visits, seed was not always kept under appropriate conditions. Seed was observed in drill seeder grain drills, mixed bags with limited tag information, and offsite under unknown conditions. All of these conditions could expose the seed to conditions that may have impacted the germination percentage; and therefore revegetation success.

**Table 3c. Eastern Plains Seed Viability Testing Results**

| Seed Viability | | | | | |
|---|---|---|---|---|---|
| **Species** | **Actual** | | | **Seed Tag Germination** | **Percent Change** |
| | **Germination** | **Dormant** | **Hard** | | |
| Oats | 94% | 0% | 0% | 98% | -4% |
| Little Bluestem | 39% | 10% | 0% | 95% | -48% |
| Thickspike Wheatgrass | 95% | 0% | 0% | 95% | 0% |
| Prairie Sandreed | 46% | 0% | 0% | 94% | -51% |
| Prairie Junegrass | 88% | 0% | 0% | 84% | 5% |
| Western Wheatgrass | 92% | 2% | 0% | 85% | 11% |
| Prairie Coneflower | 79% | 3% | 0% | 98% | -16% |
| Blanketflower | 82% | 2% | 0% | 81% | 4% |
| Sand Dropseed | 4% | 60% | 0% | 91% | -30% |
| Sideoats Grama | 89% | 4% | 0% | 95% | -2% |
| Blue Flax | 63% | 0% | 0% | 50% | 26% |
| Purple Prairie Clover | 25% | 0% | 64% | 98% | -9% |
| Blue Grama | 78% | 0% | 0% | 93% | -16% |

## 3.3 “Forensic” Revegetation Analysis

The objective of the forensic revegetation analysis was to determine the revegetation processes and crucial growth variables that contributed to the success of historical construction sites. This task compared methods used at former construction sites within three CDOT regions to determine if consistent revegetation variables contribute to revegetation success. Data was reviewed and interpreted to test the hypothesis that improved revegetation will occur if contractors follow specifications and contract requirements based on historical evidence.

These selected forensic survey locations were assumed to be revegetated according to CDOT specification and oversight by CDOT landscape architects. Former construction sites within the following areas and regions were visited by the TerraLogic team:

- US-285 (Region 1)
- I-25 Former TREX (Region 1)
- Berthoud Pass (Region 3)
- Powers Boulevard (Region 2)
- US-50 (Region 1)

### 3.3.1 US-285 Forensic Survey

The US-285 project was constructed in three phases starting in 1994. The construction of this US-285 corridor project was completed in 2002. The forensic survey was conducted on June 19, 2014. The following summarizes the survey findings:

***Seed Mix Evaluation***

A comprehensive seed mix was developed by CDOT and placed in the construction SWMP. It was assumed that the seed mix data provided by CDOT in the SWMP were actually used for revegetation seeding on the US-285 Project.

The seed mix developed for the US-285 Project had 10 separate species with 4 of those consisting of forbs and shrubs. PLS per square foot was approximately 133, in which grasses accounted for approximately 78 PLS per square foot; approximately 60 percent of the seeds on a PLS basis. Approximately 30 percent of the grasses on a PLS basis were cool grasses. The majority of the grasses in the seed mixes (60 percent) were bunch grasses. The utilized seed mix had too many PLS per square foot and is heavy on warm season grasses. This mixture of introduced species such as *Thinopyrum intermedia* and *Trifolium hybridium* does not meet CDOT internal policies.

***The Forensic Survey Results***

Total percent-vegetative cover of the site ranged from 90 to 100 percent, with only one measurement point location in all the transects having no vegetative cover. Basal cover, live leaves lying on the soil surface, and base of the plants, ranged from 0 to 50 percent with an average basal cover of 24 percent. From a site stabilization perspective the revegetation success at this construction site was very high.

Looking at revegetation from an ecological perspective, the Overall Health Evaluation Index of the entire revegetation area achieved scores from 2 to 4, with the reference area receiving a score of 4 (Table 3d). The average score of 3.4 for all five plots was close to the reference value of 4 for Overall Health Evaluation. The Native Plant Abundance Index ranged from 2 to 5, with the reference area receiving a score of 5. The average score of the five plots surveyed was 3.4, slightly above average, indicating the presence of native plant species, though native species were not as abundant as in the reference plot. The Ecological Continuity Index scores ranged from 2 to 5 with an average rating of 3.2 with the reference area receiving a score of 5. Similar to the Native Plant Abundance Index score, Transect 2 scored the lowest on Ecological Continuity Index due to the lack of species diversity in this revegetated area (Table 3d).

Good plant diversity, good soil drainage and a lack of noxious weeds resulted in the relatively high Overall Health, Native Plant Abundance and Ecological Continuity Indices scores for US-285.

Comparing native species identified during the transect sampling versus the seeds planted during the revegetation portion of the project indicates a lack of continuity. The percentages of plants identified for each transect versus what was planted ranged from 0 to 36 percent. The reference area identified had one species along the transect that was in the project seed mix. The average for all plants identified compared to the seed mix was approximately 17 percent, including the reference area. Therefore, a majority (83 percent) of the plants identified along the transects were likely establish due to recruitment and soil seed bank rather than the actual seed mix used. This indicates that the seed mix selected did not help in promoting revegetation success.

The number of forbs and shrub species observed within the transects, excluding the reference transect, ranged between 0 to 18 percent to the seed mixture. The percentage of forbs and shrubs was very low when compared to the percentage in the seed mix (41 percent). This discrepancy between the seed mix and the established ROW forbs and shrubs was potentially due to mowing and/or herbicide spraying.

Four of the ten plant species in the seed mix were not seen in the five survey plots: big bluestem, blue grama, sideoats grama, sheep fescue, and woods rose. Over the past 12 years since construction, 40 percent of the seed mix species were not observed, and this leads to a conclusion that the seed mix should have been more closely matched to the native plants within the construction project area.

**Table 3d. Summary Revegetation Scores for Hwy 285 Vegetation Transect Surveys**

| Plot/ Transect | Reference Plot (#4) | Scores | | | Grazing/ Herbivory | Overall Health | Native Plant Abundance | Ecological Continuity |
|---|---|---|---|---|---|---|---|---|
| | | Canopy cover | Bare ground | Basal cover | | | | |
| **1** | | 100% | 0% | 10% | 1 | 4 | 3 | 4 |
| **2** | | 100% | 0% | 50% | 1 | 3 | 2 | 2 |
| **3** | | 100% | 0% | 30% | 2 | 2 | 4 | 4 |
| **4** | **Reference** | **100%** | **0%** | **20%** | **2** | **4** | **5** | **5** |
| **5** | | 100% | 0% | 30% | 1 | 4 | 4 | 3 |
| **6** | | 90% | 0% | 0% | 1 | 4 | 4 | 3 |
| | **Ave. Score*** | **98%** | **0%** | **24%** | **1.2** | **3.4** | **3.4** | **3.2** |
| *Excludes reference; 1-low, 5-high. | | | | | | | | |

## *3.3.2 TREX I-25 Forensic Survey*

The on and off ramps at the interchange at Interstate 25 (I-25) and University Boulevard (Blvd) in Denver were chosen as the second forensic survey location for the study. The combined freeway construction and light-rail expansion project occurred from March 1998 to May 2001 (US DOT, 2001). The former T-REX Transportation Expansion Project (previously known as the Southeast Corridor Project) area is a prime example of the revegetation challenges within an urban environment after major highway construction.

### ***The Forensic Survey Results***

Total percent canopy cover of the site ranged from 60 to 100 percent. The reference areas had 100 percent canopy cover. Basal cover, live leaves lying on the soil surface, and base of the plants, ranged from 0 to 40 percent with an average basal cover of eight percent. From an erosion control and site stability context, the revegetation success at this construction site does not meet the 70 percent-vegetative criteria at Transect 2 when compared to the reference site location.

Looking at revegetation from an ecological perspective, the Overall Health Index of the revegetation system achieved scores ranging from 1 to 3, with the reference area receiving a score of 3. The average Overall Health Index score of 2.5 for all seven transects indicates poorer than average health, indicating a high presence of noxious weeds, weedy species and lack of native plants (Table 3e).

**Table 3e. Summary Revegetation Scores for TREX Vegetation Transect Surveys**

| Plot/ Transect | Reference Plot (#4) | Scores | | | Grazing/ Herbivor y | Overall Health | Native Plant Abundance | Ecological Continuit y |
|---|---|---|---|---|---|---|---|---|
| | | Canopy cover | Bare ground | Basal cover | | | | |
| **1** | | 90% | 0% | 0% | 2 | 2 | 2 | 3 |
| **2** | | 60% | 0% | 0% | 3 | 3 | 2 | 3 |
| **3** | | 70% | 0% | 0% | 2 | 3 | 3 | 3 |
| **4** | **Reference** | **100%** | **0%** | **0%** | **2** | **3** | **5** | **5** |
| **5** | | 90% | 0% | 0% | 3 | 2 | 4 | 5 |
| **6** | | 100% | 0% | 40% | 3 | 3 | 4 | 4 |
| **7** | | 90% | 0% | 10% | 1 | 2 | 4 | 4 |
| | **Ave. Score*** | **83%** | **0%** | **8%** | **2.3** | **2.5** | **3.2** | **3.7** |

*Excludes reference; 1-low, 5-high.

Native Plant Abundance Index scoring ranged from 2 to 5, with the reference area receiving a score of 5. The lowest scores were at Transect 1 and Transect 2 due to the low biodiversity, potentially caused by the severe mowing and chemical deicing in the area. The reference area (Plot 4) was given a Native Plant Abundance Index score of 5. The average score of all five plots was 3.7, indicating better than average ecological continuity. Thus the revegetation achieved a very good vegetative blending within the natural landscape.

The percent of plants identified versus what were planted ranged from 0 to 50 percent. The reference area had three species identified along the transect that was in the project seed mix. The average plants identified compared to the seed mix was approximately 29 percent, including the reference area. Therefore, 71 percent, of the plants identified along the transects were establish due to recruitment and soil seed bank and not from the original seed mix.

The number of forbs and shrubs observed within the transects, excluding the reference transect, ranged between 0 to 33 percent of the total species observed. Only one out of 60 points was of the originally planted forbs and shrubs identified in the transect observations. This discrepancy between the seed mix and the established ROW conditions illustrates that forb and shrub establishment from seeds can be difficult. It also indicates that subsequent re-seeding of desirable seed forb species may be required in ROW areas.

It was noted that nine of the 13 plant species within the seed mix were observed within the measured transects. Within the reference area only three seed species out of 13 were observed. The percentage of plant species in the seed mix that were identified through transect measurements ranged from seven to 53 percent. In the reference area only 20 percent of the seed mix species were growing along the transects. This difference between the species planted versus the plant species present indicates that the seed mix might not have been appropriate for the site.

### *3.3.3 US-40 Forensic Survey (East Side of Berthoud Pass)*

The Environmental Assessment of Berthoud Pass construction project was completed in 1987 and the road construction was completed in 2004. Some of the key environmental study issues were water quality, erosion control and slope stability. A few innovative requirements on contractors were incorporated to enhance plant establishment such as field planting of native vegetation, trees selection based on alpine environment adaptation and a plant establishment incentives (US-40 Berthoud Pass Booklet, 2003).

#### ***The Forensic Survey Results***

Vegetative transects were performed to determine the percent-vegetative cover and to assist in evaluation of the seed mix used at the site. Qualitative scores were obtained for the general health and ecology of the revegetated area. Plot 5 was deliberately surveyed in two sections; 5-1 on the east side of a stream (without topsoil treatment), and 5-2 on the west side of a stream (4 inches of topsoil), to illustrate any differences in vegetation due to the application of topsoil versus no application of topsoil. This topsoil comparison was part of a qualitative experiment by CDOT and important in the forensic study’s hypothesis.

Total percent canopy cover of the site ranged from 60 to 100 percent. The reference areas had 100 percent canopy cover. Basal cover, live leaves lying on the soil surface, and base of the plants, ranged from 0 to 40 percent with an average basal cover of 17 percent. From an erosion control and site stabilization context, the revegetation success at this former construction site for Transect 5-1 does not meet the 70 percent-vegetative criteria relative to the baseline condition. Based on personal communications with Michael Banovich (CDOT technical leader) this area did not have topsoil salvaged or placed while the area near Transect 5-2 had topsoil placement. Transect 5-2 had 20 percent greater canopy cover and 20 percent less bare ground than Transect 5-1. This demonstrates the importance of topsoil use in accomplishing revegetation success.

Looking at revegetation from an ecological perspective the Overall Health Index of the revegetation achieved scores from 3 to 5, with the two reference areas receiving scores of 4 and 5. The lowest Overall Health Index score was observed in Transect 4 due to the presence of weedy non-native species. The average score of 3.8 (Table 3f) for all six plots indicates above average health, mainly because of the lack of noxious weeds, the presence of native plants, good recruitment of new species, as well as good growth of the species in the seed mix.

The Native Plant Abundance Index scoring ranged from 3 to 5, with the reference areas receiving a score of 5. The lowest score was at Transect 1 and Transect 5-1 due to the low biodiversity. All vegetation seen in all plots appeared healthy and four of the six plots had an abundance of Plant Diversity Index beyond the seed mix species with ratings above 3, indicating that native plants had colonized the roadside corridor. The Ecological Continuity Index scores ranged from 3 to 5, again with the reference area receiving a score of 5. The non-topsoil portion of Transect 5, Transect 5-1, received the lowest ecological continuity score of all transects measured.

Comparing species identified during the transect sampling versus the seeds planted during the revegetation portion of the projects indicates a lack of seed mix continuity. Percent of plants identified versus what was planted ranged from 0 to 50 percent. The reference area had three species identified along the transect that was in the project seed mixes. The average plants identified compared to the seed mix was approximately 29 percent, including the reference area. Therefore, 71 percent of the plants identified on transects were established due to recruitment and soil seed bank versus the actual seed mix used.

The number of forbs and shrubs observed within the transects, excluding the reference transect, ranged between 0 to 33 percent of those originally planted. This discrepancy between the seed mix and the established ROW conditions illustrates that forb and shrub establishment from seeds can be difficult. It also indicates that subsequent seeding of desirable forb species may be needed and local species may eventually establish and dominate the site.

**Table 3f. Summary Revegetation Scores for Berthoud Pass Vegetation Transect Surveys**

| Plot/ Transect | Reference Plot (#3-1 & 3-2) | Scores | | | Grazing/ Herbivory | Overall Health | Native Plant Abundance | Ecological Continuity |
|---|---|---|---|---|---|---|---|---|
| | | Canopy cover | Bare ground | Basal cover | | | | |
| **1** | | 80% | 20% | 20% | 1 | 4 | 3 | 4 |
| **2** | | 80% | 10% | 10% | 2 | 4 | 4 | 5 |
| **3-1** | **Reference** | 100% | 0% | 40% | 3 | 5 | 5 | 5 |
| **3-2** | **Reference** | 100% | 0% | 0% | 4 | 4 | 5 | 5 |
| **4** | | 90% | 10% | 40% | 3 | 3 | 3.5 | 4 |
| **5-1** | | 60% | 20% | 0% | 4 | 4 | 3 | 3 |
| **5-2** | | 80% | 0% | 0% | 4 | 4 | 4 | 5 |
| **6** | | 100% | 0% | 30% | 3 | 4 | 5 | 5 |
| | **Ave. Score*** | **82%** | **10%** | **17%** | **2.8** | **3.8** | **3.8** | **4.3** |
| *Excludes reference; 1-low, 5-high. | | | | | | | | |

Four of the 10 plant species within the seed mix were not observed within the measured transects. Within the reference area only three seed species out of ten were observed, which indicates that the seed mix used was not representative of the native plant community or was impacted by maintenance operations.

### *3.3.4 Powers Boulevard Forensic Survey*

An area south east of the new ramp configuration of North Gate Blvd and I-25 in Colorado Springs, Colorado was chosen by CDOT as the fourth of five survey locations. The roadway construction was completed in 2013, making this vegetative survey the first since roadway construction completion. The Powers Blvd site was not fully constructed and just the road grade has been established with no paving or other activities conducted. At the time of the site visit, the project was still under the SCP. The plot sites were diverse in slope, aspect, and sunlight, but all were within the revegetated area. The Powers Blvd site makes for an excellent reference site for the project area and for all the former project sites, since it has not been impacted by vehicles and maintenance activities.

On August 8, 2014, five ROW surveys, and one off-ROW survey were used for native vegetation baseline reference within the south east interchange area of I-25 and North Gate Blvd just south of the Bass Pro Shop Development. One location (Plot 3), which was not impacted by construction activities, was found to be suitable for baseline conditions.

### ***The Forensic Survey Results***

Total percent canopy cover of the site ranged from 80 to 100 percent. The reference areas (Transect 3) had 100 percent canopy cover. Basal cover, live leaves lying on the soil surface, and base of the plants, ranged from 10 to 50 percent with an average basal cover of 22 percent. From an erosion-control compliance standpoint, the revegetation success at this construction site exceeded the 70 percent-vegetative criteria at all transect location compared to the reference area. This demonstrates that under the right conditions successful revegetation can be completed within one year. This site had not received any mowing or herbicide applications based on the information received by CDOT.

From an ecological perspective, the Overall Health Index of the revegetation project achieved scores from 4 to 5, with the reference area receiving a score of 4. Transect 1 received the highest score at the Powers Blvd Project. The average score of 4.2 (Table 3g) for all six plots indicated above average health, mainly because of the lack of noxious weeds, the presence of native plants, and good recruitment of new species, as well as good growth of the species in the seed mix.

The Native Plant Abundance Index ranged from 3 to 5, with the reference area receiving a score of 5. The lowest score was at Transect 4 due to the low biodiversity. Native plant abundance in Plot 4 was slightly less than in Plot 5; these two plots were adjacent and different soil amendments between these two plots could account for the difference.

The Ecological Continuity Index scores ranged from 4 to 5, with the reference area receiving a score of 5. These scores indicated both great revegetation successes for erosion control and site stabilization, with also natural and ecological success.

## Table 3g. Summary Revegetation Scores for Powers Blvd Project Vegetation Transect Surveys

| **Plot/ Transect** | **Reference Plot (#3)** | **Scores** | | | **Grazing/ Herbivory** | **Overall Health** | **Native Plant Abundance** | **Ecological Continuity** |
|---|---|---|---|---|---|---|---|---|
| | | **Canopy cover** | **Bare ground** | **Basal cover** | | | | |
| **1** | | 80% | 10% | 30% | 2 | 5 | 4 | 4 |
| **2** | | 90% | 0% | 20% | 1 | 4 | 5 | 4 |
| **3** | **Reference** | **100%** | **0%** | **50%** | **2** | **4** | **5** | **5** |
| **4** | | 90% | 0% | 30% | 1 | 4 | 3 | 4 |
| **5** | | 80% | 10% | 10% | 2 | 4 | 4 | 4 |
| **6** | | 90% | 0% | 20% | 2 | 4 | 4 | 4 |
| | **Ave. Score*** | **86%** | **4%** | **22%** | **1.6** | **4.2** | **4** | **4** |

*Excludes reference; 1-low, 5-high

Comparing species identified during the transect sampling versus the seeds planted during the revegetation portion of the projects indicated a lack of seed mix integration with the natural environment. It was noted that only two of the 12 plant species within the seed mix were not observed within the measured transects. Within the reference area only two seed species out of 12 were observed. Percent of plants identified along the transects versus what were planted ranged from 27 to 45 percent. The average percent of plants identified compared to the seed mix applied was approximately 36 percent. Therefore, 64 percent of the plants identified along the transects were established due to recruitment and original soil seed bank and not from the actual seed mix. This indicates that the seed mix used did not represent the native plant community or was impacted by CDOT maintenance Operations.

Four of the 10 plant species within the seed mix were not observed within the measured transects. Within the reference area only three seed species out of ten were observed, which indicates that the seed mix used may not have been representative of the native plant community or was impacted by maintenance operations.

### *3.3.5 US-50 Forensic Survey (Grand Junction)*

The 3.5 mile section of US-50 between state highway 141A, east of Grand Junction, and state highway 141, (Unaweep/Tabeguache Byway), was chosen as the fifth forensic vegetation survey location in Colorado. Construction was completed in July, 1999. This site illustrates the challenge of roadside revegetation after major highway construction in the high Western Plateau, semi-desert environment.

#### ***The Forensic Survey Results***

Vegetative transects were performed to determine the percent-vegetative cover and to assist in evaluation of the seed mix used at the site. In addition, qualitative scores were obtained for the general health and ecology of project area. Total percent cover of the site transects ranged from 40 to 100 percent. Bare ground ranged from 0 to 50 percent. Basal cover, live leaves lying on the soil surface, and base of the plants, ranged from 0 to 40 percent with an average basal cover of 14 percent. The survey sites within the study area were drastically different, which is demonstrated from the high variability between site indices scores. The single reference site identified at the US-50 project area likely does not represent the multiple ecozones within the construction area; therefore a representative baseline could not be well established, with only one reference area.

Looking at revegetation from an ecological perspective (Table 3h) the Overall Health Index of the revegetation achieved scores from 1.5 to 3, with the reference area receiving a score of 3. The lowest Overall Health Index score was observed in Transect 3.

The Native Plant Abundance Index score was based on the presence of native species and the site's species diversity. Reference Plot 6 was given a score of 5, and the average score for the six roadside plots surveyed was 2, which was below average, thus indicating poor recruitment of native plant species.

The Ecological Continuity Index scores ranged from 2 to 5, again with the reference area receiving a score of 5. The average score of all five plots was 1.8, indicating poor ecological continuity. The most logical explanation for this low score is that the native landscape is plateau grassland integrating into shrublands, in which shrubs can take many years to establish.

**Table 3h. Summary Revegetation Scores for US-50 Vegetation Transect Surveys**

| **Plot/ Transects** | **Reference Plot (#6)** | **Scores** | | | **Grazing/ Herbivory** | **Overall Health** | **Native Plant Abundance** | **Ecological Continuity** |
|---|---|---|---|---|---|---|---|---|
| | | **Canopy cover** | **Bare ground** | **Basal cover** | | | | |
| **1** | | 100% | 0% | 0% | 3 | 2.5 | 3 | 3 |
| **2** | | 100% | 0% | 40% | 3 | 2 | 3 | 2 |
| **3** | | 90% | 10% | 20% | 2 | 1.5 | 1 | 1 |
| **4** | | 80% | 20% | 10% | 1 | 2 | 2 | 1 |
| **5** | | 40% | 50% | 0% | 2 | 2 | 1 | 2 |
| **6** | **Reference** | **70%** | **20%** | **30%** | **4** | **3** | **5** | **5** |
| | **Ave. Score*** | **82%** | **16%** | **14%** | **2.2** | **2** | **2** | **1.8** |

*Excludes reference; 1-low, 5-high

Comparing species identified during the transect sampling versus the seeds planted during the revegetation portion of the projects indicates a lack of the seed mix representing the native species in this arid ecozone. Percent of plants identified versus what was planted ranged from 0 to 40 percent. The reference area evaluated did not have any of the seed mix species used on the project. The average plants identified compared to the seed mix was approximately 20 percent. Therefore, 80 percent of the plants identified along the transects were established due to recruitment and soil seed bank and not from the actual seed mix.

Fifteen years after seeding this stretch of highway, it would be expected that more of the seed mix species would have been established along the ROW. This discrepancy between the seed mix and the established ROW vegetative condition is likely due to mowing and/or herbicide spraying. Even though the compost requirements in the SWMP appeared correct, little if any evidence of compost application was observed through soils evaluations. In one instance some compost application was evident in a two foot radius, however outside this radius no evidence of compost application could be observed. This lack of compost application could have severely hindered revegetation success on these marginal soils.

There was the lack of seed mix species observed in the reference plot, indicating that closer evaluation of the native species is required to develop an appropriate seed mix. None of the existing site’s grasses were part of the seed mix for this project. Using undisturbed reference areas to help develop seed mixes would potentially have increased the revegetation success.

### 3.3.6 Forensic Survey Overview

An examination of the index scores of the point-line transect surveys relative to the reference transects at all five sites were evaluated. The site that rated the highest compared to their reference sites was the Powers Blvd Project site. This site was the most recently revegetated site, but also no mowing or herbicide treatments were conducted on this site. The poorest overall site compared to their reference site was US-50. The US-50 site had the poorest soils, dried climate and poorest revegetation success. During the soils review very little if any compost or soil amendments could be identified on US-50. After the US-50 site, the TREX site had the lowest native plant abundance and ecological continuity. These low scores compared to their reference sites are likely due to the intense roadway maintenance activities such as herbicide applications, low cut mowing, and deicing agents used in this area. In addition, seed mixes were not designed based on native plants present at the former construction sites and lack of proper soil amendments (i.e. compost and topsoil) applications could have negatively impacted reclamation success.

Site specific ecozone revegetation approaches need to be evaluated and used to select seed mixes and establish revegetation strategies especially in the most severe environments (west slope and high elevation) within Colorado like the US-50 forensic survey area.

Urban environment revegetation is difficult due to intense maintenance activities such as mowing, deicing chemical and herbicide applications. In these areas, more introduced species that may withstand intensive maintenance operations, as oppose to native species may be required. Weed pressure also appears to be greater in these areas and should be considered when developing appropriate seed mixes.

The ground cover, such as the introduced alsike clover, requires some consistent moisture and is less tolerant of drought than the grasses which were included in the seed mix (USDA Plants Website). This clover should not be included in a seed mix in Colorado because it is an introduced specie and lacks drought resistance. One recommendation for future revegetation would be to include a native drought-resistant ground cover that has been observed in the vicinity, such as *Eriogonum umbellatum*, sulfur-flower buckwheat, and seed it after roadside grasses have been established and weeds have been eradicated by spraying.

The use of a diverse native seed mix with appropriate ground covers will improve the ecology of the sites and make the revegetated areas more attractive to pollinators. Beneficial pollinators can further improve the ecosystem by increase the total diversity of the system and natural increasing the recruitment and establishment of important native species. Using species like Sulfur-Flower Buckwheat attracts a wide variety of bees and other native pollinators.

## 3.4 Revegetation Survey of CDOT Construction Project Engineers

A revegetation survey of CDOT construction project engineers was developed and distributed to 160 CDOT engineers by the CDOT Research team via Google Forms. The purpose of the survey was to test the hypothesis that the majority of CDOT construction and design engineering representatives have gaps in the basic technical and CDOT process knowledge needed to successfully manage revegetation activities. The survey was sent to a broad population of construction and design engineers to obtain unbiased sampling of the CDOT engineering population (Appendix H). All responses were anonymous to encourage honest engagement. The questions focused on several themes of CDOT practices. These themes can be summarized as:

- Oversight of reclamation
- Revegetation success
- Communication between CDOT employees and contractors
- Project responsibility

Below is a summary of the responses based on the four themes listed above.

In regards to revegetation-field oversight, nine questions (1 - 9) were related to what efforts are made to achieve revegetation success. Practices such as reviewing plans, confirmation of site preparations, and level of detail required in plans were presented in the questions. Suggestions were solicited for improvement of the revegetation success. Oversight is critically important in ensuring that the contractors are executing the revegetation actions via CDOT specifications. In the survey, consistently 30 to 40 percent of the engineering respondents indicated that little contractor oversight is performed or that plans are changed in the field with little oversight or knowledge from CDOT.

The lack of appropriate contractor oversight is highlighted in three questions (2, 3 and 9). Question 2 asked the respondents to prioritize inspecting contractor performance; 27 percent of the respondents rated this task as moderate or low. When asked how they confirmed the revegetation process (Question 3) 49 percent responded that they rarely visually inspect the process in the field. When asked if a CDOT expert should assist in a monthly review of revegetation conditions, 51 percent of the respondents said no. Due to the percentages being spread amongst the multiple answers for the questions posed in this theme, it is evident that CDOT employees have varying views on who is responsible for revegetation oversight and the correct amount of contractor oversight. This is the case in many of the other survey questions, which shows that there is no clear directive for contractor oversight of the revegetation process.

Revegetation success concepts were discussed in three questions (10 - 12). The main theme of these questions was the perceived reasons for revegetation success and thoughts for improving reclamation success. Based on the responses to these questions, it is evident that highly qualified and good contractors are key to gaining revegetation success. Fifty-one percent of the respondents indicated that successful revegetation projects are due to the contractor. When revegetation failed the highest percentage of respondents believe it is due to contractors. These two questions definitely indicate that the competency of the revegetation contractor is a key component of any successful revegetation project.

In regards to communication, three questions (13 - 15) were asked that address the level and frequency of communication between CDOT representatives and contractors. Communication regarding frequency and timing of contact with the contractors were incorporated into the questions. It was asked if the contractor expectations were discussed early in the project. Based on the results, it is apparent that communication is either lacking, ill timed, or directed to the wrong person or group during the revegetation process. For example, for question 13, 65 percent of the people rarely or only sometimes contact the prime contractor when revegetation success is not achieved. Communication between CDOT and the revegetation contractors is severely lacking which likely leads to poor revegetation due to a lack of project revegetation goals, objectives and expectation understanding.

In regards to project responsibility, seven questions (16 - 22) were asked to address assumptions about who is responsible for certain revegetation aspects of a project. Responsibility of the CDOT landscape architect and Environmental Specialist was discussed. It was also asked whose responsibility it is to handle monitoring of revegetation progression as well as post-construction vegetation cover analysis. Coordination among CDOT departments was also discussed. Again, similar to contractor oversight responses, the lack of a majority percentage on many of the questions indicates that there are varying opinions or understandings about which person is responsible for certain aspects of the revegetation process. Question 17 provides an example on the varying thoughts on responsibility of monitoring vegetation success. Four out of the six possible answers on question 17, received greater than 30 percent of the responses. There is a lack of clarity on who is responsible for monitoring revegetation success for CDOT.

There were other survey responses that would potentially affect the success of revegetation practices:

- Twenty-one percent of respondents identified that the RPEM is the first person to consult if there are proposed revegetation changes in the field; 16 percent recognize the use of the landscape architect.
- In confirming the implementation of soil preparation and seeding, 82 percent indicate they do visual field confirmations before and not during these activities.
- For identifying who is responsible for monitoring revegetation success 18 percent chose the RWPCM, 14 percent chose the maintenance representative and 17 percent selected the TECS; whereas 8 percent chose the landscape architect. This shows a wide range of understanding for who is monitoring revegetation success.
- Respondents stated that only 4 percent of the contractors have a high level of understanding of CDOT revegetation specifications.
- Twelve percent of the respondents coordinate with CDOT maintenance to prevent herbicide applications on areas undergoing revegetation.
- A large percentage of respondents (42 percent) felt that a more detailed revegetation plan within the SWMP would be helpful in project revegetation.
- Thirty-three percent of the respondents felt that support from landscape architects would be helpful to assist in soil preparation and seeding.

Each survey question developed by CDOT identifies a practice that is significantly undefined in achieving success of a revegetation project. The vast array of survey responses identifies inconsistency in practices and understanding among CDOT engineers as it relates to the CDOT revegetation process. This survey indicates that the revegetation oversight, communication, and responsibility structure within CDOT is not well known or established. By not knowing who is responsible for the varying parts of revegetation, this condition is likely negatively impacting revegetation success and adding additional environmental liability and cost to CDOT. It is important for CDOT to train their employees and contractors regarding the roles and responsibilities of individuals during the revegetation process so that proper oversight, communication and authority can be performed. It is believed that if improvements are made in these areas, significant cost savings and improved revegetation success can be obtained.

## 3.5 Revegetation Cost Analysis

A cost analysis was performed on CDOT projects to assess the estimated costs incurred by CDOT maintenance for SCP compliance management. The purpose of this cost analysis was to test the hypothesis that CDOT Engineering and Maintenance management have underestimated the cost and level of effort for project revegetation and resulting rework. Three types of cost analysis were conceptualized. The first was a best-case versus worst-case revegetation scenario that compared TREX (assumed best case site) to I-25 between Lincoln and Lone Tree (worst case site). The second cost analysis study involved the calculation of monthly mean and range of financial costs incurred by CDOT maintenance for SCP compliance management for nine projects. The second cost analysis was based on the time from SCP compliance management acceptance by CDOT maintenance to SCP deactivation. The third cost analysis centers on CDOT maintenance costs for erosion control and revegetation re-work for 12 projects located in CDOT Region 1.

### *3.5.1 Best Case-Worst Case Revegetation Scenario*

The first cost analysis was a best-case versus worst-case revegetation site scenario that compared I-25 TREX (assumed best case) to I-25 between Lincoln and Lone Tree (worst case). These project were selected due to similar revegetation challenges in an urban setting with high traffic volumes and intensive operation and maintenance practices along I-25. This financial analysis could not be performed due to the lack of accurate cost and level of effort data inputted into the SAP system. Table 3i provides a summary of the data collected for both I-25 sites for a five year period (July 01, 2009 through July 01, 2014).

**Table 3i. Stormwater Compliance Cost Comparison**
**(TREX versus I-25 Near Lincoln)**

| Project | Activity Code | Activity Name | Total Cost | Hours |
|---|---|---|---|---|
| TREX (MP 204-206) | 223 | EnviroTempBMPs | $3,357.32 | 68 |
| | 224 | EnviroPermanentBMPs | $5,502.21 | 134.5 |
| | 225 | Enviro 30-day Inspection | No data | No data |
| I-25 (MP 181.5-193) | 223 | EnviroTempBMPs | $0.00 | 0.00 |
| | 224 | EnviroPermanentBMPs | $717.13 | 20 |
| | 225 | Enviro 30-day Inspection | No data | No data |

Over a five year period there was no environmental 30-day inspection time (labeled as “Enviro 30-dayInspection” in table) logged into the database system for either project area. The I-25 Lincoln to Lone Tree section is still under a SCP and no inspections have been performed according to this database (Activity Code 225).

### *3.5.2 Maintenance Costs for SCP Compliance*

The second cost analysis involved a cost assessment for nine former construction projects where SCPs were recently deactivated. The purpose was to calculate the monthly means and ranges of financial costs incurred by CDOT maintenance for SCP compliance management. Activity Type Codes 223, 224 and 225 were evaluated from August 1, 2010 to September 22, 2014. The projects that were selected (with mile post designations) and the associated Activity Type Code costs were as follows:

- I-25 (MP 0-7.5)
    - No data for 223, 224 and 225
- US 24 (MP 291-298)
    - 223- drainage/culvert cleaning; $1,882.98
    - No data for 224 and 225
- US 24 and Ellicott Highway
    - No data for 223, 224 and 225
- US-50 (MP 270-278)
    - No data for 223, 224 and 225
- SH 266 to SH 71
    - No data for 223, 224 and 225
- SH 14 (MP 71.2-72.1)
    - 224- Hydroseed; $6,544.25
    - No data for 223 and 225
- SH 185b (MP 8.7-26.4)
    - 223 - BMP and hot plant yard clean up; $2,299.84
    - No data for 224 and 225

- US 491 (MP 27-37)
    - 223- Pick up erosion logs; $199.62
    - 223- Pick up BMPs; $226.26
    - 223- Pick up temp. BMPs; $221.71
    - 223- Pick up temp. BMPs; $581.51
    - 223- Remove silt fence; $328.97
    - No data for 224 and 225
- SH 491 (MP 51.1 -69.6)
    - No data for 223, 224 and 225.

There was no Activity Type Code 225 for 30-day environmental inspections for any of the above projects. The use of Activity Codes 223 and 224 appear to be inconsistent and probably inaccurate for projects having four years durations. No meaningful analysis could be performed with the quality of this database. Perhaps another database contains the actual maintenance hours and costs for environmental inspections. Although the sites are deactivated, it should be verified that environmental monitoring records exist that are complaint to SCP requirements.

### *3.5.3 Region 1 Revegetation Rework*

CDOT Region 1 compiled cost information on 12 selected projects with both open and deactivate SCPs (Mulqueen, 2014). Financial costs needed to correct erosion control and revegetation problems was compiled for evaluation. These financial costs to correct deficiencies came out of non-project funds; and therefore assumed to be financed by the CDOT maintenance budget. Table 3j provides the project name, permit status, costs and scope of the deficiencies. The data also identifies the duration of time needed for SCP deactivation

The total CDOT Region 1 Maintenance costs associate with correcting erosion control and revegetation deficiencies was $622,500 as of October 27, 2014. These non-project funded activities included re-grading, re-seeding, removal of BMPs, rip rap rundown installation, and reinstalling erosion-control blankets. At the time of this report development, there are still projects with open SCP and increased costs are expected. It has been estimated that the Kit Carson Bridge Project may ultimately cost CDOT up to $1,300,000 (Banovich, 2014).

**Table 3j. Non-Project Costs for Erosion Control and Revegetation Deficiencies**

| Project | Project Acceptance Date | SCP Effective Date | SCP Deactivation Date | Duration (years) | Costs to Correct Deficiencies |
|---|---|---|---|---|---|
| Hogback Park and Ride | 2010 | 2006 | 2013 | 3 | $212,000 |
| Arapahoe Road and Parker | 2014 | 2010 | 2014 | 0 | `$71,000 |
| I-24 and Arapahoe | 2012 | 2009 | 2013 | 1 | $26,000 |
| SH 224 and I-76 | 2011 | 2009 | 2014 | 3 | $40,000 |
| C 470 Median Cable | 2013 | 2010 | Open | | $130,000 |
| C 470 Bike Path | 2011 | 2009 | Open | | $31,000 |
| C 470 and Santa Fe Flyover | | 2010 | Open | | $10,000 |
| Kit Carson Bridge | | 2007 | Open | | $90,000 |
| Bridge Replacement US 36 and 80th Avenue | 2012 | 2010 | Open | | $7,500 |
| I-25 and 84th Bridge Replacement | 2014 | 2010 | Open | | $5,000 |
| Comanche Bridge | 2013 | 2011 | Open | | $5,000 |
| SH 119 Main Street | | 2010 | Open | | $35,000 |
| Total | | | | | $662,500 |

*Duration (years) = Deactivation-Acceptance

## *3.5.4 Economic Benefits of Completing Reclamation Successfully the First Time*

It has been demonstrated in the literature that it is cost effective to perform site revegetation (reclamation) correctly the first time as oppose to revegetating after failure. TerraLogic's team member David Chenoweth (Western States Reclamation) co-authored a paper entitled "*The Economic Benefits of Completing Reclamation Successfully The First Time for Oil and Gas Sites*" (Appendix J) for the International Erosion Control Association (February 18, 2010). It was determined that for oil and gas well sites, over 50 percent cost increases over initial revegetation costs can result for sites that failed to establish vegetation correctly. This cost does not account for additional environmental management, consultant costs, and potential stormwater fines (Chenoweth, Jacobs, Kruckenberg, Rissa, Whiteley, 2010). Similar costs savings could be realized by CDOT by instituting correct revegetation practices into the project the first time.

It was determined that, for oil and gas facilities, the most common revegetation failures are associated with three factors; the lack of available, quality of topsoil; the lack of implementation of stormwater BMPs; the lack of clear upfront revegetation design; and follow up performance supervision. These revegetation failure factors are the very same factors identified in the construction revegetation QC assessment (Section 3.0). The technical paper identified the following critical factors for successful revegetation:

- Initial planning and site surveys
- Topsoil placement and re-grading
- Seed mixture design
- Seeding methods
- Mulch and erosion-control fabrics
- Stormwater BMPs
- Proper maintenance and monitoring

Many of these critical factors have been discussed in this Results and Discussion Section and identified in the following Conclusions and Recommendations (Section 4.0).

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations detailed in this section are based on actual field observations and measurements, cost analysis, a CDOT employee survey, and cost evaluations to improve the CDOT revegetation process. An ineffective revegetation process can have a profound impact on CDOT environmental and regulatory risk and liability and result in efficient spending of finite monetary resources. This project focused on the effectiveness and challenges facing the CDOT revegetation process.

One of the main challenges facing CDOT in order to reduce revegetation costs and SCP duration is based on the current CDOT system of post-construction responsibilities and process. There is a condition of competing interests associated with revegetation. Project Engineers and contractors are in a hurry to finish the project and move onto the next project. This conclusion is based on conversations with RWPCM, CDOT landscape architects, TECS and other CDOT personnel interviewed for this project. It appears that revegetation is one of the last considerations of many projects, and that the vegetative success factors can easily be overlooked or ignored. This condition has the high potential of impacting CDOT maintenance financial resources toward the end of the construction project and into the post-construction phase. CDOT maintenance is left with a potentially high environmental and regulatory compliance risk due to potential soil erosion discharges from poor contractor revegetation performance.

A high level CDOT management discussion about changing the mindset of closing out construction projects as soon as possible and better defining long-term revegetation responsibilities could be considered. The overall CDOT cost of performing revegetation correctly the first time during construction as opposed to leaving CDOT maintenance to perform revegetation rework needs to be considered under a life-cycle cost perspective. Contractors need to be made more responsible for successful revegetation implementation and establishment. CDOT should consider other post-construction contract mechanisms with qualified landscape contractors to manage revegetation, SCP responsibilities and long-term site stabilization.

CDOT has established specific specifications for revegetation and landscaping during roadway construction. The most common challenge facing projects to achieve revegetation success is the lack of contractor oversight and direction. It has been shown in this research study that CDOT revegetation specifications and RFP requirements are being ignored or only partially followed by contractors. There appears to be a lack of qualified CDOT representatives to provide oversight of contractors during critical revegetation stages such as seed management, soil preparation and seeding. This observation was common to most the construction sites visited, and was mentioned as a common problem by other DOT's landscape professionals.

There is a CDOT revegetation process that if followed will result in improved revegetation success with the potential for reduced SCP duration and CDOT maintenance rework costs. There is no formal QC for the revegetation process, and there is a lack of onsite verification and oversight due to limited CDOT resources. Many of the following conclusion and recommendations are directly and indirectly associated with this QC challenge.

## 4.1 Topsoil and Subsoil Management

Soil compaction that inhibits root growth and is not in conformance to CDOT specification 212.06 for soil preparation was noted at four out of five active construction projects. Excessive soil compaction occurs in areas with routine construction traffic, heavy equipment usage, or non-tilled soils. The potential for successful revegetation is hampered by not adequately preparing the soil, such as soil tilling to at least 4 inches, prior to seeding as required by CDOT. High soil compaction can also lead to greater surface erosion due to limited storm water infiltration and decreased plant growth.

- **Recommendation:** Compaction is a major problem and specifications need to be enforced in the field by trained CDOT personnel. Compacted areas should be tilled prior to topsoil placement and seed bed preparation. It is recommended that the entire ROW be deep ripped using an agricultural type deep ripper. The shanks on the back of a grader or dozer should be used to remove soil compaction. Soil compaction relief should be performed to a minimum depth of 16 inches with a preferred depth of 24 inches. In some instances, ripping the soil surface only once is not adequate and contractors often bid to do it just once. Depending on equipment used, this soil preparation could be accomplished in a single pass or could take multiple passes. It is recommended that a CDOT landscape architect or trained representative observe the soil ripping and tilling operations. Improved revegetation success and erosion control should result from this action.

Topsoil needs to be treated as a critical on site resource for successful revegetation. Topsoil salvage methods with minimal soil importation showed improved revegetation success in this study (Berthoud Pass, US-285 and Powers Blvd). At the majority of active construction sites topsoil stockpiles were not properly developed, managed, utilized and monitored. Due to improper topsoil salvaging techniques it has been necessary for some projects to rely on non-topsoil material or imported soils to promote native plant growth. At one construction site, the integrity of the topsoil stockpiles had been compromised with the introduction of construction debris and imported soil.

- **Recommendation:** Salvage suitable soil material at a depth based on an actual soil profile depth specific to the project areas. A trained revegetation professional should perform the soil profile survey and determine appropriate topsoil salvage depths prior to establishing grading plans. Generally it is recommended that at least 6 inches of material be salvaged when practical. Additional salvaged material up to 12 inches should be considered based on soil profile information. It is critical to monitor projects during soil removal to ensure topsoil is properly conserved and stockpiled (AASHTO, 2011). Field observation protocols for topsoil stockpiles and/or topsoil berms should be developed and implemented to promote topsoil integrity. Topsoil salvage material should not be used for stormwater BMPs or other process that could lead to degradation of soil quality. Signage should be used to denote topsoil salvaged material to prevent the introduction of road debris, waste materials and imported soil into the topsoil. Existing CDOT specifications for topsoil salvaging should be enforced upon contractors.

Lack of soil organic matter is negatively affecting soil quality and revegetation success. The soil observation, sampling and analysis of the five active construction sites revealed that four sites had no evidence of compost application, although all of the areas had compost requirements. Many times this removal of compost from the project plan was performed without adequate chemical data to support the decision and was performed without notifying the project engineer. Forensic survey sites that previously used compost were shown to experience successful revegetation results (Powers Blvd and Berthoud Pass). Organic matter is responsible for many aspects of good vegetative establishment and growth. These aspects include increased soil water retention, increased soil aggregation, increased infiltration, increased macro and micronutrient supply, increased nutrient retention, and decreased compaction.

- **Recommendation:** In general, greater rates of compost should be added to the revegetated areas to offset the organic matter losses due to mineralization. Compost should be applied and incorporated during the placement of the topsoil material back onto the soil surface. Compost application on the disturbed areas should be highly monitored since it is one of the most important items identified to reach maximum revegetation success. The correct application and rate of compost will improve revegetation success especially on sites with poor or limited topsoil conditions. The amount of compost added should be based on initial soil testing results before construction is initiated.

Based on soil test results, additional fertilizer application was not likely required on most of the construction sites visited. Fertilizer applications should be considered if the site is characterized by extremely sandy or gravelly soils. Addition of excess fertilizer can promote weedy species and potentially cause environmental degradation if the applied fertilizer is allowed to reach surface water or groundwater. Additional project costs can be encountered if excess fertilizer is applied to the soil. No active projects sites perform soil sampling and testing to determine baseline nutrient conditions and the need for additional augmentation.

- **Recommendation:** Soil samples should be collected and tested at the planning or design stage to determine if fertilizer needs to be applied and at what amounts. Inorganic nitrogen concentrations in excess of 15 mg/kg should be managed using carbon additions to decrease potential negative effects of mineralized nitrogen. Adequate carbon should be added to the systems to reduce the total inorganic nitrogen concentration to less than 15 mg/kg (Mortvedt, et al 1996).

Imported soil at construction sites used for revegetation purposes is mostly of unknown quality and origin. Imported soils are untested for soil quality to promote successful revegetation and may contain noxious and invasive weeds that were not present prior to construction. Soil importation of low quality soil without testing was performed on one active construction site; however, it is a common practice at many CDOT construction projects.

- **Recommendation:** Soil importation should only be conducted as a last resort when less than 4 inches of suitable top soil material is identified through field verified soil descriptions and testing by a CDOT landscape architect or soil scientist. Laboratory testing for noxious weeds, nutrients and organic matter should be conducted on the imported soil material and native topsoil prior to project area transport. Imported soil material should be of equal or better physical and chemical quality than the native material for revegetation purposes. All imported topsoil for revegetation should be approved by the CDOT landscape architect.

  If importation of soil is deemed necessary, the soil storage area should be strategically located and an IWMP should be prepared and implemented. The IWMP should identify potential weeds (both common, noxious and invasive) that may need to be managed and eradicated. The IWMP, which should be a component of a landscape design plan, should clearly state how weeds will be managed using integrated weeds management BMPs. The contractor and/or CDOT maintenance should be responsible for implementing, updating and maintaining the IWMP until the SWMP is deactivated.

## 4.2 Seed Section and Establishment

Native plant establishment in the initial year of revegetation is important to control noxious weeds and begin to stabilize soils. The initial plant establishment should be performed with both a short and long-term stabilization and maintenance strategy. Seed mixes at the visited active construction sites and at the forensic survey sites did not use a mixture of grasses for short and long term establishment.

- **Recommendation:** Seed mixes should be developed with predefined short-term and long-term revegetation goals. Native species such as slender wheatgrass and prairie junegrass should be used in CDOTs seed mixes. These grasses are quick to establish and can create productive cover in the initial years of establishment. The additional benefit of these grasses is that they are not long lasting plants and will give way to native species that are slower to establish such as green needlegrass. This method of seed mix design will increase overall revegetation success and decrease weedy species infestation by providing appropriate cover throughout the revegetation process. By decreasing weedy species management, CDOT can reduce herbicide treatment and the associated time and cost to reach revegetation success.

Current seed mixes and basic SWMP landscape plans used by all the visited construction and forensic projects appear to be based on regional vegetation zones or ecosystem communities. This practice is too broad to determine the appropriate site-specific seed mixes. Seed mixture success was marginal to poor at many forensic locations where a small percentage of seed species were present as plants. In addition, most forensic sites' seed mixes did not contain the same native species found in the undisturbed reference sites; therefore site specific native species were not considered in the seed mixture that could increase revegetation success

- **Recommendation:** Performing a baseline species inventory to determine the existing site specific vegetation communities at a future project site is desirable (Steinfield and Riley, 2007). The existing plant communities are already adapted to local site conditions and have a greater likelihood of survival following construction activities. A project reference site needs to be selected by a qualified botanist, range scientist or landscape architect to determine which plant species are best adapted for the site revegetation (Armstrong, 2007). Review of pre-existing vegetation and incorporation into the approved seed mixture will augment the topsoil's native plant seed bank and improve overall revegetation success. This species inventory could be done during the NEPA project clearance period so appropriate seed mix information can be incorporated in the Project RFP. Seed selection needs to consider the soil salinity conditions in light of CDOT deicing applications. Improved cost savings on projects should be realized when the correct seed mixture is used for revegetation.

A review of all project seed mixtures indicated that most of the project did not use the drill seed rate to an average of 50 to 60 seeds (PLS) per square foot, which is an accepted BLM standard in the western United States (Bureau Land Management, 2011). Existing seeding rates on visited active construction sites and forensic survey locations are too high for projects that results in wasting seed and budget while decreasing potential revegetation success (Harper-Lore, 2014). More seeds does not equate to revegetation success since a limited quantity of resources (water, nutrient and sunlight) are available for growth. An overabundance of seeds per square foot can lead to intense competition for water and nutrients that may not be available in the soil. This could negatively affect vegetation diversity or lead to eventual die off of the vegetation community.

- **Recommendation:** The application rates of PLS for revegetation projects needs to be revisited by CDOT. CDOT should evaluate the rates of PLS application based on the ecozone and native plant densities of the pre-construction area. It is also recommended that CDOT review seeding rates in the future to address potential climate change variables similar to the State of Wyoming DOT. Landscape architects should anticipate climate change impacts to future and existing revegetation areas. Seed mixes and rates should be reviewed and approved by a landscape architect with consideration to warm versus cool season grasses, sod forming versus bunch grasses, and preexisting plant communities. Based on predictive models increases in carbon dioxide concentrations and temperature may facility the movement to warmer season plant versus cool season plant species (Morgan et al. 2009).

There is inconsistency in seeding applications within the seasonal seeding windows specified in CDOT specification 212.03. Four out of five visited active construction were not in compliance with this specification. The long term success of plant germination and sustained growth is based on seeding within these windows. Seeding outside of approved seeding windows can increase the amount of time required for revegetation success thus increasing the potential for revegetation rework.

- **Recommendation:** Contractors should not be allowed by the project engineer to seed outside the CDOT specification seeding windows unless approved by a CDOT landscape architect. Forcing contractors to coordinate with the CDOT landscape architect for a site-monitoring visit just prior to seeding and the development of landscape design plan will help eliminate this common noncompliance condition.

Seed germination could be problematic due to poor handling of seed by the contractors. Based on the forensic studies, little bluestem had very poor establishment rates; however, the seed germination testing shows that little bluestem’s germination rates had huge viability. There was high variability observed from seed germination testing when compared to seed tag information. It is possible that poor handling and management of the seed could be leading to poor revegetation success especially for sensitive seeds like little bluestem. Improving seed handling could increase revegetation success by increasing the number of viable seeds being placed in the soil.

- **Recommendation:** Ensure proper seed handling techniques by contractors according to specifications. All contractors should have to verify that seed is maintained under appropriate conditions. Conduct periodic seed viability testing especially at the beginning of revegetation actions. Any seed that has an individual species germination percentage less than 15 percent of the seed tag's guaranteed germination percentage should be considered out of specification. When a seed viability sample is considered out of specification all prior seeding is suspect and should potentially redone. Seed tag documentation provided to CDOT from contractors must have date of seeding performed and area where the seed was installed, in addition to any state law requirements. Any seed tag documentation missing the date of seeding should be considered out of date and out of specification for seed germination. Areas where seed germination testing is greater than 365 days should be considered as non-viable and retested and areas should be reseeded with proven viable seed.

All active construction projects visited were not documenting drill seeding equipment calibrations and ensuring proper operation. Drill seeding equipment needs to be calibrated and checked routinely to ensure proper seed placement and application in the field. Drill seeding is one of the most important actions within the revegetation process. Drill seeding depth and placement is critical to ensure intimate contact between seed and soil material. The calibration ensures that the CDOT specified seed application (PLS per acre) is being applied correctly on the amended soil. Drill seeder problems were noted on the only active construction site undergoing revegetation activities.

- **Recommendation:** Drill seeding depth and calibration actions should be documented and verified by a CDOT landscape architect or other qualified CDOT employee before seeding actions are initiated by the contractor. Site visits by the CDOT landscape architect or qualified representative should observe and verify calibrations and proper operation of the equipment. Equipment seeding depths and calibrations should be documented by the landscape contractor. This recommendation will improve seed placement and promote better soil to seed contact at the correct depth.

De-icing agent applications, especially in Colorado urban environments, can increase soil salinity concentrations; and therefore decrease revegetation success, especially if non-salt tolerant plant species are used for revegetation. Poor revegetation results were recorded at the TREX forensic site that is potentially related to deicing activities.

- **Recommendation:** In areas where large quantities of de-icing agent are anticipated to be utilized, seed mixes should be specifically designed for high salinity soils. CDOT should consider zonal seed mixes in that as distance increases from the roadway less salt-tolerant native species could be used. The use of plant species with high salt-tolerances should be approved by the CDOT landscape architect. .

Forensic studies have shown that most revegetated areas lack established areas for forbs and shrubs. Revegetation areas that are likely to have dense stands of weedy species should not plant or seed forbs and shrubs during initial stages of revegetation. It is possible that CDOT maintenance herbicide treatments are affecting the viability of forbs and shrubs at critical times.

- **Recommendation:** An IWMP should be established as part of the project landscape design plan. The IWMP should be devised to control known weedy species within the first two years of revegetation. It is recommended that during the initial revegetation management phase, forbs and shrubs should not be planted in the revegetated area, since they will be severely limited by weedy species control methods. If forbs and shrubs are desired in the revegetated area they should be planted at a later date once the weedy species are controlled. Delaying planting of the forbs and shrubs will limit the use of expensive forb and shrub seeds that have minimal chances of success due to current weed management techniques.

Decrease in pollinator and other selected species is a concern at both the national and state levels due to habitat changes and pesticide. Federal government agencies are under a 2014 Presidential directive to identify ways to improve insect-pollinator environments. CDOT should be proactive in developing attractive habitats conducive to pollinators whenever possible.

> **Recommendation:** Future revegetation strategies should include a native drought-resistant ground cover that has been observed in the vicinity, such as *Eriogonum umbellatum*, sulfur-flower buckwheat, and seed it after roadside grasses have been established and weeds have been eradicated by spraying. This will allow for the establishment of broadleaf plants and a decreased negative effect on pollinator species.

## 4.3 Landscape Design

The elements embedded in the CDOT SWMP (Tab 1) lack sufficient detail to contractors and project engineers for revegetation. Limited SWMP information is provided for seed mixes, amendments and corrective stabilization; however, specific revegetation scheduling, responsibilities, corrective actions and success metrics are absent. A detailed revegetation plan (landscape design plan) would be advantageous to CDOT and the contractor to fully understand CDOT revegetation expectations.

- **Recommendation:** A project specific landscape design plan should contain elements associated with revegetation design, planning, implementation, monitoring, corrective actions, QC and responsibilities. The landscape design plan should specify the contractor expectations, responsibilities and performance metrics and should also address key revegetation elements such as early planning, clear objectives and stakeholder collaboration. The development and use of a landscape design plan has a high potential to improve revegetation success via improved contractor performance resulting in reduced maintenance costs (Armstrong, 2011).

CDOT landscape architects are not fully engaged in the early stages of the project with design and/or project engineers to develop revegetation strategies. Active construction sites visited had minimal to no involvement by CDOT landscape architects. The landscape architect should be used to identify revegetation problems early, protect existing vegetation, create final vegetation treatment details, develop RFP language and provide design input to better promote revegetation (Steinfield and Riley, 2007). No integrated revegetation planning process seems to exist from project planning-design through permit deactivation and complete site stabilization.

- **Recommendation:** CDOT landscape architects need to coordinate early with the CDOT project designers, project engineers and maintenance representatives to give direction and support on grading, revegetation, erosion control, drainage issues and final site stabilization issues. The landscape architect should be used to develop revegetation contract language to achieved desired results in the field (Armstrong, 2009).

There were no formal performance measures used at any active construction projects to gauge revegetation success and contractor performance. Performance measures provide a mechanism for CDOT to identify revegetation successes and problems in the field that allow for the development of adaptive management strategies.

- **Recommendation:** A project specific landscape design plan should contain a QC plan that describes how the contactor will be measured against performance measures (AASHTO, 2011). The performance measures should be based on each project's revegetation goals and objectives (Steinfield and Riley, 2007) which are not currently specified in the CDOT SWMP. Performance measures should be monitored at a given frequency or during critical revegetation process actions by the CDOT landscape architect or qualified representative.

There is no final metric or performance measures that needs to be achieved by the contractor in order for CDOT maintenance to accept the existing revegetation conditions after construction is completed. Based on conversations with most RWPCMs, only a visual observation is apparently used by CDOT maintenance to accept the transfer of revegetation and erosion control responsibilities. The development and utilization of performance measures will help reduce CDOT maintenance's environmental risk and cost liabilities by accepting only project areas that are undergoing effective revegetation.

- **Recommendation:** CDOT maintenance personnel need to have a better understanding of revegetation requirements and erosion control conditions when accepting revegetation and stormwater compliance responsibilities. CDOT maintenance should consult with a CDOT landscape architect for technical support and guidance when accepting revegetation and erosion-control responsibilities. A revised Maintenance Punchlist should be considered that better identifies performance measures for revegetation as part of a CDOT post-construction process. A Revegetation Monitoring and Inspection Tool is located in Appendix K to aid CDOT maintenance and the landscape architect in evaluating revegetation status and progress over time. The monitoring tool is essentially a QC checklist that should be used routinely to evaluate revegetation progress and identify and correct problems early.

Revegetation problems needing immediate attention in the field are not being considered and given the same level of importance as a Corrective Action under the CDOT Erosion Control Program. Active projects do not routinely document revegetation problems during periodic inspections, monthly inspections or during RECAT inspections. It was not observed at any visited constriction site that contractors received CDOT 105 notifications due to revegetation issues.

- **Recommendation:** Corrective actions for revegetation should be entered in the ESCAN database for documentation and potential CDOT 105 actions that would lead to contractor damages. There is currently little incentive to monitor revegetation progress. Identifying problems the same way as erosion-control problems can lead to identifying problems early, with improved monitoring and compliance. Decision support systems such as or similar to an Environmental Management System can provide landscape architect benefits in managing revegetation costs, benefits, opportunities and risk (AASHTO, 2011).

There are inconsistencies and lack of detail on the existing CDOT methodology to determine percent-vegetative cover (CDOT, 2002). This observation was noted for all active construction sites and was mentioned by interviewed CDOT personnel. Active construction projects use qualitative measures such as pictures to establish pre-construction vegetative conditions, while some projects use one transect to represent large area of variable vegetation. Most active construction sites visited in this study failed to provide pre-construction vegetative surveys. An environmental risk to CDOT occurs when formal accepting or initiating SCP deactivation using inconsistent and poor measurement techniques.

- **Recommendation:** Specifications and guidance should be developed that detail the exact methodology to be used to determine pre and post-construction percent-vegetative cover conditions. CDOT needs to reevaluate and modify this methodology to ensure improved consistency, accuracy and proper use. CDOT should develop a training module that shows how proper measurements are taken and data evaluated for pre and post-construction measurements. CDOT should coordinate with CDPHE and other agencies to develop a sound vegetative cover measurement. For example, there needs to be consistency in measuring non-natives versus native plants, locating transects based on vegetative units and seasonal timing of measurements. The revised methodology should eventually be specified in a CDOT specification. This recommendation will reduce short term environmental risk to CDOT associated with deactivating a SCP via a formal CDOT signature to CDPHE.

There could be a potential conflict of interest if the revegetation contractor is responsible for measuring pre and post-construction vegetative cover conditions that are critical to deactivate the SCP. Based on conversations with active construction sites the TECS, RWPCM and landscape architects, contractors are used to establish pre-construction vegetative cover surveys. The potential exists for the contractor to place measurement transects in optimum locations or to count noxious weed species as part of the vegetative cover. There could be a potential incentive for the contractor to prematurely deactivate the SCP to receive final payment.

- **Recommendation:** Qualified CDOT representatives or an independent third party consultant should perform both the pre and post-construction percent revegetation measurements and data analysis. This will avoid a potential conflict of interest by contractors and provide less regulatory risk to CDOT. CDOT should securitize and approve percent revegetation measurements and analyses for design-build projects before the SCP deactivation request is sent to CDPHE.

Final site stabilization endpoints for projects are not well defined by CDOT. Much of the revegetation focus is on achieving the regulatory 70 percent pre-construction vegetative cover and deactivating the SCP; however, there may be some residual environmental risk to CDOT after permit deactivation. Depending on the reliability of the percent-vegetative calculation or the physical characteristics of the site, there may be some exposed soil areas that could erode and be a continuing source of pollution to local water resources.

- **Recommendation:** As part of a landscape design plan, the permit-deactivated area may still need to be monitored based on site characteristics such as slope steepness, soil type, extent of vegetative cover, etc. The CDOT landscape architect or qualified personnel should visit site conditions and make a determination if specific erosion-control BMPs and site monitoring needs to continue.

The landscape establishment contract requirements for post-construction revegetation and site stabilization between CDOT and the prime contractor appears not to be consistent among projects and CDOT regions. Contractor noncompliance to the contract's revegetation requirements was a common concern voiced by most interviewed CDOT representatives. It is not well detailed as to the contractor's revegetation responsibilities after construction and into the post-construction phase of the project.

- **Recommendation:** A new or revised CDOT post-construction program should be considered to achieve consistent stormwater management practices among all CDOT regions. CDOT specifications should be revisited for greater consistency and clarity in regards to contractor revegetation expectations during construction and post-construction. Currently CDOT specifications do not specifically identify one person other than the project engineers who is responsible for success for the revegetation life cycle. Contractor performance measures based on contract and scope of work documentation should be identified the landscape design plan.

CDOT landscape architects are not fully engaged early in the project design, construction and maintenance process as it relates to revegetation and final site stabilization. All active construction projects visited have experienced some revegetation problems that include improper seed mix usage in RFPs, incorrect soil amendments, poor seed installation, lack of revegetation monitoring and inadequate communication between the project engineer and CDOT landscape architect.

- Recommendation: The landscape architect can help reduce potential erosion impacts, protect existing vegetation, identify final vegetation treatment details, develop RFP language and provide design input to better promote revegetation (Steinfield and Riley, 2007). No strategically integrated revegetation process that involves the landscape architect seems to exist from project planning-design stage through permit deactivation and complete site stabilization. The landscape architect should influence the design and grading plans of the project that will aid in erosion control and reduce BMP costs. Figure 11 provides a process for landscape architect involvement in the planning, design, construction and maintenance stages that should be considered for CDOT projects.

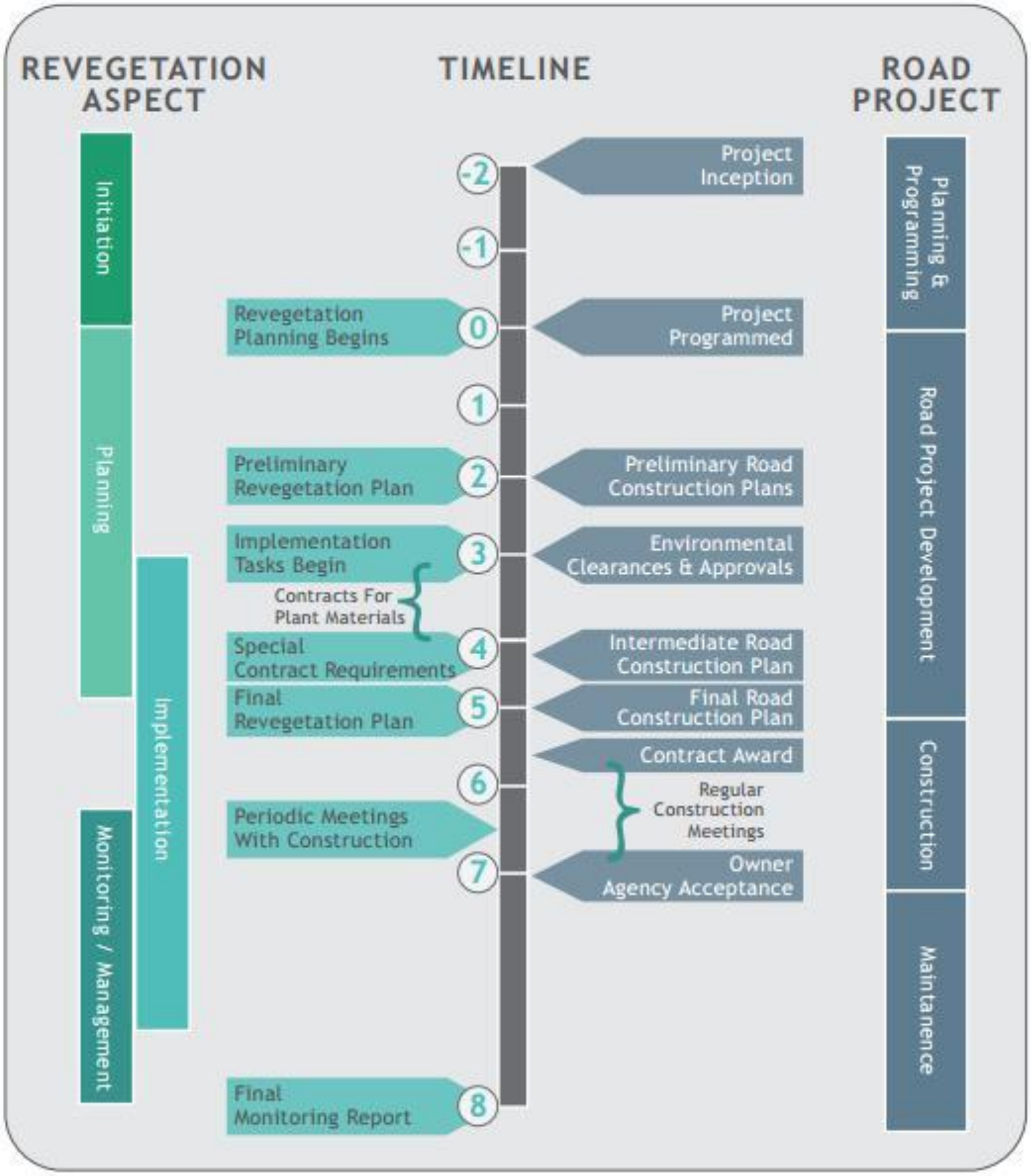

**Figure 11. Revegetation coordination in the project process diagram (Steinfeld, 2007).**

## 4.4 Construction Management

There is a consistent lack of contractor conformance to CDOT revegetation specifications (Sections 212, 213 and 214). The majority of the active construction sites exhibited a wide range of specification non-conformances that has a high potential of negatively affecting the success of revegetation on CDOT projects. As previously mentioned, soil amendment requirements, stockpile management, and soil preparation, to name a few, are often times ignored by many contractors. These non-conformance issues are extending the time required to reach revegetation success and site stabilization and have the potential for revegetation rework. This extended and unnecessary amount of time to reach revegetation success results in increased costs and environmental liability to CDOT maintenance, while managing the SCP.

- **Recommendation:** CDOT needs to provide the training, resources and methodologies necessary for CDOT representatives to monitor contractor revegetation performance. CDOT regions and/or the Environmental Programs Branch (EPB) should provide qualified resources throughout the revegetation process to achieve full site stabilization in a cost effective manner. Landscape architects, RWPCMs, and perhaps maintenance representatives need to provide contractor oversight during and immediately after construction. Ignoring revegetation specifications in the field without project engineer knowledge or approvals will impact revegetation success and result in additional costs to CDOT maintenance.

Contractors are oftentimes making unilateral decisions about not adhering to or modifying specifications in the field without project engineer knowledge or approval. Other times, project engineers are being asked to approve modifications to revegetation requirements specified in RFPs or specifications. Many project engineers make revegetation changes without fully understanding the revegetation strategy impacts. This condition was observed in 4 out of 5 active construction sites visited during this research project.

- **Recommendation:** Project engineers need to contact a CDOT landscape architect for guidance when making decisions that can affect the overall site revegetation strategy. Potential short circuiting of the revegetation process by contractors has a huge impact on revegetation success and duration. Unilateral decisions have a high potential to impact CDOT maintenance budgets. Project engineers who are asked to approve modifications to revegetation requirements specified in RFPs or specifications need to make informed decisions. These project engineers have acknowledged that they are not knowledgeable to make technical revegetation modification decisions.

There has been very limited revegetation oversight by CDOT personnel during critical points in the revegetation process. There has been no or very limited communication between the landscape contractor and the CDOT landscape architect during critical times such as percent-vegetative cover determinations, soil preparation, seeding, and revegetation monitoring. There are not the same type of field-construction responsibilities for revegetation as for erosion control; the TECS is not responsible for revegetation specification compliance. Direct revegetation process verification at critical times was performed at 1 out of 4 active construction sites. Based on CDOT interviews, this QC action is rarely performed.

- **Recommendation**: The landscape design plan should identify critical revegetation activities that need to be monitored, verified and documented. Contractors should be required to contact the CDOT project engineer and CDOT landscape architect to coordinate onsite observations and monitoring before critical actions are performed. This is especially critical during soil preparation, amendment addition, and seeding**.** The landscape design plan should initially be developed by a qualified landscape architect and maintained throughout the roadway design phase (Armstrong, 2007).

There is very limited revegetation communication and performance expectation expressed between the CDOT landscape architect and the landscape contractors during the environmental pre-construction meeting and throughout the project. No active construction sites visited had CDOT representatives discuss revegetation expectations with the contractors early in the project.

- **Recommendation:** It is important for the CDOT project engineer and landscape architect to discuss revegetation expectations early in the process with the prime contractor and their landscaping contractor. It has been shown in the literature and acknowledged in the information survey that having a contractor who understands the need for a successful revegetation outcome is critical to revegetation success (FHWA, 2011). The components of a landscape design plan and relevant specifications should be reviewed and understood by the contractor. Revegetation should be added as a discussion item in the environmental pre-construction meeting agenda. If the landscape contractor has not been selected at the time of the pre-construction meeting, a separate meeting between the CDOT landscape architect and the prime and landscape contractors should be conducted prior to any revegetation actions. The contractor's understanding of the revegetation requirements should be discussed, agreed upon and documented.

Revegetation knowledge, inspection methods and understanding of specifications was determined to be a common deficiency among most CDOT project engineers, RWPCMs and contractors. Based on project interviews, it was expressed by most CDOT field representatives that they do not have the necessary revegetation background and expertise to make revegetation decisions and be able to assess contractor progress. The results of the Revegetation Survey of CDOT construction project engineers Survey indicated a lack of revegetation process understanding at an engineering and contractor level. For example, only four percent of survey respondents felt that the contractors have a high level of understanding of CDOT revegetation specifications; therefore, landscape subcontractors would also greatly benefit from revegetation training to better understand CDOT policy and expectations.

- **Recommendation:** Revegetation training should be a requirement for CDOT project engineers, RWPCMs, landscape contractors and CDOT maintenance representatives who are making project revegetation decisions. An overview of CDOT revegetation strategies, specifications, expectations, documentation requirements, QC, performance measures, site-monitoring and contract commitments would be important training elements.

Design-build projects represent a unique revegetation challenge to CDOT. Prime contractors are generally the permit holders of the SCP and are under the requirement to obtain 70 percent-vegetative cover relative to pre-construction conditions to achieve permit deactivation. CDOT is the ultimate owner of the ROW where the project resides; however, they have limited power in directing contractors. At the active construction sites visited, no routine CDOT revegetation inspections occurred and only routine monthly erosion-control inspections and RECAT inspections were performed by CDOT. For example, on one design-build project, it was identified that the CDOT RFP requirements for seed mixes and soil amendments were lacking in detail. Contractors apparently made unilateral decisions on seed mixes and the elimination of soil amendments. The potential for poor pre and post-construction vegetative cover measurement accuracy generated by contractors may represent some residual risk to CDOT after the project is completed.

- **Recommendation:** Revegetation expectations for design-build projects need to be very detailed in the RFP that will provide little room for contractor interpretation. Any changes and modifications to this revegetation scope of work should be approved by a CDOT landscape architect. The contract and/or scope of work should specify that a detailed landscape design plan, as part of the SWMP, be approved by a CDOT landscape architect before construction activities initiate. The contract needs to allow CDOT the ability to monitor specific revegetation actions and compliance to the landscape design plan. CDOT has a vested interest in the final revegetation outcome since they own the ROW area.

## 4.5 Maintenance and Operations

A cost savings analysis for doing revegetation correctly the first time on CDOT projects has not been developed to date by CDOT maintenance management. The total cost savings that would be achieved by eliminating or reducing revegetation rework, and obtaining expected revegetation results the first time has not been calculated by CDOT. Revegetation rework costs monitored by Region 1 show high revegetation rework costs at former and existing permitted projects with an estimate cost of $622,500 for 12 projects.

It has been demonstrated by research based studies that it is very cost effective to perform site revegetation (reclamation) correctly the first time, as opposed to revegetating after plant failure. It was determined that for oil and gas well sites, over 50 percent cost increases over initial revegetation cost, equating to an additional $20,000 - $40,000 per project, can result for revegetation sites that failed (Chenoweth, 2010). Revegetation conditions and processes between oil and gas operations and CDOT construction projects are very similar.

- **Recommendation:** CDOT should initiate a research study on identifying revegetation life-cycle costs for a broad spectrum of CDOT projects. Life-cycle cost analysis should be performed on projects within different CDOT regions, varying ecozones, project complexity, and site characteristics. A cost benefit analysis should be performed to identify the cost savings of doing revegetation correctly the first time by taking into account rework costs, erosion control, revegetation monitoring, reduced mowing, herbicide treatment, and post-construction BMP maintenance.

The CDOT SAP system used for tracking revegetation maintenance activities was ineffective and of no value for two cost analyses. The maintenance activity codes for temporary erosion-control BMPs, permanent BMPS, and environmental 30-day inspections were either non-existent or appeared to be inaccurate. It was determined that it is not possible for CDOT maintenance management to measure the revegetation actions and make sound financial resource decisions for future improvement.

- **Recommendation:** CDOT maintenance management needs to establish a data input protocol for maintenance operations relative to post construction activities including revegetation. A system needs to be established that will allow CDOT maintenance to monitor erosion control and revegetation costs over time. High, or unexpected maintenance costs can be flagged, and revegetation issues can be resolved early before costs escalate.

There is a lack of herbicide application coordination and communication between the CDOT project engineer and/or CDOT landscape architect and CDOT maintenance. As per discussions with landscape architects and landscape contractors, uncoordinated broadcast herbicide spraying has hindered project revegetation activities on several visited active construction projects. A well-coordinated IWMP needs to be developed and implemented as part of a project specific landscape design plan. Lack of maintenance coordination is making revegetation efforts inefficient and wasting financial resources. It is counterproductive to have CDOT maintenance be responsible for final revegetation results when they are hindering the revegetation process by herbicide applications.

- **Recommendation:** The CDOT project engineer and/or the CDOT landscape architect or qualified representative should coordinate with the regional maintenance representative responsible for herbicide applications on or near revegetated ROW areas. CDOT maintenance is responsible for the success of revegetation upon written acceptance of the punchlist and SCP; therefore, they need to communicate with their maintenance counterparts to coordinate herbicide applications. Herbicide application should be consistent with sound IWMP protocols established by CDOT. CDOT maintenance may need to spot spray areas to control noxious weeds instead of using broadcasting applications in areas undergoing revegetation (Harper-Lore, 2014)**.**

CDOT maintenance mowing operations tend to be aggressive and performed approximately the same time every year. This practice was noted on all forensic survey sites except for Powers Blvd site. Mowing operations can lead to a monoculture of increasing non-native grasses, such as smooth brome, and noxious weeds. The mowing operations decrease overall revegetation performance and are unnecessary costs if revegetation is performed correctly during the construction phase. Mowing often promotes weedy plant infestations, especially if performed at inappropriate times. It was especially observed that mowing heights were extremely low at the former TREX; where numerous areas experienced exposed soil as a result.

- **Recommendation:** CDOT needs to re-evaluate their mowing strategies within the ROW area, especially near revegetation areas. Mowing frequency should be reduced to promote active vegetative growth while keeping weed heights acceptable. A new mowing strategy will reduce costs and promote more diverse and desirable plant species. Maintenance can save significant amounts of money in the long run if they can used hardy, adapted vegetation that needs minimal maintenance such as mowing and herbicide treatment (AASHTO, 2011).

Table 4a provides a summary of the conclusions and recommendations and rationale detailed in the text above. The priority level is based upon the ease of implementation, regulatory risk, and cost effectiveness. These priority levels should be reviewed and modified as needed to aid in implementation.

### Table 4a. Summary of Conclusions and Recommendations

| Category | Conclusion | Recommendation | Rationale | Priority |
|---|---|---|---|---|
| Topsoil and Subsoil Management | High soil compaction affecting successful revegetation; routine noncompliance to specification 212.06 | Use dozer shank to rip soil initially prior to tilling; multiple passes may be needed; ensure specification 212.05 compliance | High compaction affects root growth | High |
|  | Improved topsoil removal and salvaging management needed; no BMPs and signage for segregation | Remove topsoil based on soil actual profile depth determination; prevent introduction of non-topsoil and debris | Poor topsoil salvage techniques noted at most construction sites | High |
|  | Lack of soil compost application for organic matter | Higher rates of compost needed to enhance organic matter; 60 cubic yards per acre application a general consideration; evaluate amount based on soil testing | Improves organic matter in soil for vegetative growth; some project areas ignored application | High |
|  | Too much fertilizer being applied to topsoil based on soil testing results | Collect soil samples prior to construction and evaluate fertilizer application rates if any | Excess fertilizer can contribute to surface and groundwater quality issues; may promote establishment of weed vegetation; unnecessary financial resources being expended | Medium |
|  | Poor quality imported soil is being used for revegetation without quality testing | Imported soil should be tested for nutrients, organic matter, and noxious weeds before transport and use | Poor quality soil will hinder revegetation efforts and cause proliferation of noxious weeds | Medium |
| Seed Selection and Establishment | Seed mixes at the active construction sites and at the forensic sites did not use a mixture of grasses for short and long term establishment. | Seed mixes should be developed with predefined short-term and long-term revegetation goals. Native species should be used in CDOTs seed mixes. | Promotes improved stabilization by using grasses that are not long lasting plants and will give way to native species that are slower to establish | Medium |
|  | Current native seed mix approaches provided poor to marginal success in vegetation establishment | Identify seed mixes based on existing plant communities that are already adapted to local site conditions and have a greater likelihood of survival; species inventory done very early in the project design process | The cost of native seed mixes are high, and more cost efficient seed selection is needed. There will be a higher potential of plant species success if site specific native species are selected in the seed mixture. | High |

| Category | Conclusion | Recommendation | Rationale | Priority |
|---|---|---|---|---|
| | Application rates of PLS are high and have the potential of effecting successful revegetation | CDOT should evaluate the rates of PLS application based on the ecozone and native plant densities of the pre-construction area. | An overabundance of seeds per square foot can lead to intense competition for water and nutrients that may not be available in the soil. This could negatively affect stand diversity or lead to eventual die off of the vegetation community. | Medium |
| | Visited construction sites show there is inconsistency in seeding applications within the seasonal seeding windows specified in CDOT specification 212.03. | Contractors should not be allowed by the project engineer to seed outside the CDOT specification seeding windows unless approved by a CDOT landscape architect. | Decreased plant survival can be expected if seeding occurs outside the seeding window which increases the potential of re-seeding and additional costs. | High |
| | Seed viability and management may be affecting revegetation by poor storage or poor quality seed | Conduct seed viability testing especially at the beginning of revegetation actions. Ensure proper seed handling techniques by contractors according to specifications | Seed viability assessment is the first critical part of the revegetation process. Lack of viable seed early in the project will have a profound impact on revegetation and cost. | High |
| | De-icing agent applications, especially in Colorado urban environments, can increase soil salinity concentration and decrease revegetation success | In areas where large quantities of de-icing agent are anticipated to be utilized, seed mixes should be specifically designed for high salinity soils | Lack of revegetation success will be experienced due to saline soils from deicing without using salt tolerant plant species | Medium |
| | Studies have shown that most revegetated areas lack established areas for forbs and shrubs due to maintenance operations | The IWMP should be devised to control known weedy species within the first two years of revegetation. It is recommended that during the management phase forbs and shrubs not be planted in the revegetated area, since they will be severely limited by weedy species control methods. | Delaying planting of the forbs and shrubs will limit the use of expensive forb and shrub seeds that have minimal chances of success due to weed management techniques. | Medium |
| | Federal government agencies are under a 2014 Presidential directive to identify ways to improve insect-pollinator environments. | Develop native seed mixes that attract and promote pollinating insects | Pollinating insect populations have dramatically decreased due to habitat impacts caused by herbicide and pesticide usage. Improving pollinator habitat will help improve insect populations and meet the Presidential goals | Medium |

| Category | Conclusion | Recommendation | Rationale | Priority |
|---|---|---|---|---|
| Landscape Design | Elements embedded in the CDOT SWMP lack sufficient detail to contractors for successful revegetation | A project specific and non-boilerplate landscape design plan should be developed by a qualified landscape architect or contractor. | Critical information necessary to achieve successful revegetation such as design, planning, implementation, monitoring, corrective actions, QC, and responsibilities are consolidated into one area for reference and management | High |
| | CDOT landscape architects are not fully engaged in the early stages of the project with design or project engineers to develop revegetation strategies. | Landscape architects need to coordinate early with the CDOT project designers, construction project engineers and maintenance representatives to give direction and support on grading, revegetation, erosion control, and drainage issues. | Improved revegetation success will be achieved if a coordinated strategy is developed between the landscape architect and design and construction engineers. Early involvement will reduce the potential for revegetation rework. | High |
| | There are no formal performance measures to gauge revegetation success and contractor performance throughout the CDOT revegetation process | A project specific landscape design plan should contain a QC plan that describes how the contactor will be rated against performance measures. The performance measures should be based on each project's revegetation goals and objectives | Performance measures provide a mechanism to identify revegetation successes and problems in the field that allow for the development of adaptive management strategies | High |
| | There is no final metric or performance standard that needs to be achieved by the contractor for CDOT maintenance to accept the existing revegetation conditions after construction is completed. | CDOT maintenance personnel need to have a good understanding of revegetation requirements and erosion control conditions when accepting revegetation and stormwater compliance responsibilities. CDOT maintenance should consult with a CDOT landscape architect for technical support and guidance | This action will reduce CDOT maintenance environmental and regulatory risk and cost liabilities. | High |
| | Revegetation problems needing immediate attention in the field are not being considered and given the same level of importance as erosion-control problems | Corrective actions for revegetation should be entered in the ESCAN database for documentation and potential CDOT 105 actions leading to contractor damages. | Improved corrective action awareness that can be better managed to reduce potential rework and additional costs | Medium |

| Category | Conclusion | Recommendation | Rationale | Priority |
|---|---|---|---|---|
| | There are inconsistencies and lack of detail on the existing CDOT methodology to determine percent-vegetative cover. High probability that most active construction sites do not perform pre-and post-construction vegetative surveys | Specifications and guidance should be developed that detail the exact methodology to be used to determine pre and post-construction percent-vegetative cover. | An environmental risk to CDOT occurs when formally accepting or initiating SCP deactivation using inconsistent and poor measurement techniques. | High |
| | There could be a potential conflict of interest if the revegetation contractor is responsible for measuring pre- and post-construction vegetative cover conditions that are critical to deactivate the SCP. | A qualified CDOT representatives or an independent third party consultant should perform both the pre- and post-construction percent revegetation measurements and data analysis. | This action will avoid a potential conflict of interest and provide less regulatory risk to CDOT. | High |
| | The final site stabilization endpoint for projects is not well defined by CDOT. Much of the revegetation focus is on achieving the regulatory 70 percent pre-construction vegetative cover and deactivating the SCP; however, there may be some residual environmental risk to CDOT after permit deactivation | As part of a landscape design plan, the permit-deactivated area may still need to be monitored based on site characteristics such as slope steepness, soil type, extent of vegetative cover, etc. | This will reduce environmental risk by protecting local water resources and stabilizing soils and slopes long term. | Medium |
| | The revegetation and post-construction contract requirements between CDOT and the prime contractor appears not to be consistent among projects and CDOT regions | A new or revised CDOT post-construction program should be considered to achieve consistency of stormwater management among all CDOT regions. | Improved revegetation success is expected to occur if contract expectations are identified and enforced consistently among regions. | High |
| Construction Management | There is a consistent lack of contractor conformance to CDOT revegetation specifications (Section 212, 213 and 214) | CDOT needs to provide the training, resources and methodologies necessary to monitor contractor revegetation performance. CDOT regions and/or the Environmental Programs Branch (EPB) should provide qualified resources throughout the revegetation process to achieve full site stabilization in a cost effective manner. | Improved contractor oversight and guidance during critical revegetation process times is important to ensure specifications are followed. There will be improved revegetation and cost effectiveness for projects. | High |

| Category | Conclusion | Recommendation | Rationale | Priority |
|---|---|---|---|---|
| | Contractors are oftentimes making unilateral decisions about not adhering to specifications in the field without project engineer knowledge or approvals. Other times, project engineers are being asked to approve modifications to revegetation requirements specified in RFPs or specifications. | Increased contactor performance monitoring is needed by a qualified CDOT representative. Project engineers need to contact a CDOT landscape architect for guidance when making decisions that can affect the overall site revegetation strategy. | Improved revegetation is expected to result when monitoring contractor performance to specifications. Professional revegetation guidance will help ensure revegetation is performed correctly the first time. | High |
| | There has been very limited revegetation oversight by CDOT during critical points in the revegetation process. There has been no, or very limited communication between the landscape contractor and the CDOT landscape architect | The landscape design plan should identify critical revegetation activities that need to be monitored, verified, and documented. Contractors should be required to contact the CDOT project engineer and CDOT landscape architect to coordinate onsite observations and monitoring *before* critical actions are performed | Improved communication between the CDOT landscape architect and landscape subcontractor is important to discuss expectations and have a common goal for a successful revegetation process. | High |
| | Revegetation knowledge, inspection methods, and understanding of specifications was determined to be a common deficiency among most CDOT project engineers, RWPCMs, and subcontractors | Revegetation training should be a requirement for CDOT project engineers, RWPCMs, and maintenance representatives who are making project revegetation decisions. | Training will increase knowledge of the CDOT revegetation process and specifications. Improved education will help ensure a consistent understanding of CDOT expectations and factors for success. | High |
| | Design-build Projects represent a unique revegetation challenge to CDOT. | Revegetation expectations for design-build projects need to be very detailed in the RFP that will provide little room for contractor interpretation. Any changes and modifications to this revegetation scope of work should be approved by a CDOT landscape architect. | Without oversight and communication, there is a potential for poor pre- and post-construction vegetative cover measurement accuracy generated by contractors. Project areas with poor revegetation that will require additional rework and stabilization time may be handed over to CDOT. | Medium |
| Maintenance and Operations | It is very cost effective to perform site revegetation (reclamation) correctly the first time as oppose to revegetating after plant failure. Revegetation-rework costs monitored by Region 1 show high revegetation-rework costs for former and existing permitted projects. | CDOT should initiate a research study on identifying revegetation life-cycle costs for a broad spectrum of CDOT projects. Life-cycle cost analysis should be performed on projects within different CDOT regions, varying ecozones, project complexity, and site characteristics | The life-cycle costs for various construction projects will provide a range of costs over the lifetime of a project. Cost analysis could be performed to assess if additional upfront project costs result in overall project cost efficiency. | High |

| Category | Conclusion | Recommendation | Rationale | Priority |
|---|---|---|---|---|
| | It was found that the SAP system used for tracking revegetation maintenance activities was ineffective and of no value for two cost analyses tasks. | CDOT maintenance management needs to establish a data input protocol for maintenance operations relative to revegetation. A system should be established that will allow CDOT maintenance management to monitor erosion control and revegetation costs over time. | High, or unexpected maintenance costs can be flagged and revegetation issues can be resolved early before significant costs escalate. | High |
| | There is a lack of herbicide application coordination and communication between the CDOT project engineer and/or CDOT landscape architect and CDOT maintenance. Uncoordinated broadcast herbicide spraying has hindered project revegetation activities on several visited, active construction projects. | The CDOT project engineer and/or the CDOT landscape architect should coordinate with the regional maintenance representative responsible for herbicide applications on or near revegetated right of way areas. | CDOT maintenance is responsible for the success of revegetation upon written acceptance of the punchlist; therefore, they need to coordinate with their maintenance counterparts to coordinate herbicide applications. Herbicide application should be consistent with sound integrated noxious weed management protocols established by CDOT. | High |
| | It is difficult for a CDOT maintenance representative to fully understand the level of revegetation success and overall environmental risk at the time of the written acceptance for SCP responsibilities | CDOT maintenance should seek out the services of a CDOT landscape architect or qualified representative to evaluate erosion control and revegetation conditions before accepting SCP responsibilities from the contractor; a new post-construction process should be considered that eliminates CDOT maintenance responsibility for SCP compliance | Based on conversations with CDOT RWPCM and landscape architects the level of revegetation understanding by CDOT maintenance is limited; many CDOT maintenance representatives leverage off of RWPCM, whose revegetation understanding may also be limited. | High |
| | CDOT maintenance mowing operations tend to be aggressive and performed approximately the same time every year. They can lead to a monoculture of increasing non-native grasses, | CDOT should re-evaluate their mowing strategies within the ROW area, especially near revegetation areas. Mowing frequency should be reduced to promote active vegetative growth while keep weed heights acceptable. | A new mowing strategy will reduce costs and promote more diverse and desirable plant species. Maintenance can save significant amounts of money in the long run if they can used hardy, adapted vegetation that needs minimal maintenance such as mowing and herbicide treatment | Medium |

## 4.6 Conclusions and Recommendation Summary

Revegetation is an important component to the overall project design, construction, and maintenance phases. Revegetation importance is sometime overlooked by construction projects when the main water quality focus is on erosion-control BMPs and SWMP specification compliance. It has been demonstrated in this research report that there is a high cost and expenditure of resources associated with not performing revegetation correctly the first time. The longer the duration that CDOT keeps the SCP open, the more environmental and regulatory liability CDOT is required to manage.

### *4.6.1 Hypothesis Testing*

As mentioned in Section 2.4, this research study was founded upon five basic research hypotheses based on the project goals and objectives. These hypotheses were tested using revegetation interviews, QC assessments, salvaged soil testing, top soil characterization, seed viability testing, forensic vegetative surveys, maintenance revegetation cost assessments, and a construction engineering survey . The following are the results of the hypothesis testing.

- Salvage Soil Management Hypothesis- the potential for improved plant revegetation can be achieved if nutrient and organic amendment concentrations of topsoil are known before revegetation actions initiate. It was identified that nutrient addition is not normally required for all the soils sampled in this study. There was a need for additional compost material for higher organic matter concentrations to promote plant growth. Proper topsoil removal and management was shown to be effective in promoting revegetation.
- Construction Revegetation Quality Control Hypothesis- the CDOT revegetation process is not being completely followed, especially at critical steps; and therefore, the lack of compliance is negatively affecting the rate, quality, and overall success of revegetation. This hypothesis was proven correct at most active construction sites visited in this research project. There is a lack of revegetation process QC by landscape architects or qualified revegetation professionals.
- Forensic Revegetation Analysis Hypothesis- improved revegetation will occur if contractors follow specifications and contract requirements based on historical evidence. This hypothesis was proven correct based on the forensic surveys performed at former construction sites. Proper soil preparation, amendments and seeding were deemed critical in the CDOT process success.
- Revegetation Survey of CDOT Construction Project Engineers– the majority of CDOT construction engineering representatives lack basic technical and process knowledge to successfully manage and direct revegetation activities. This hypothesis was correct based on conversations with CDOT landscape architects, RWPCMs, and the results of the engineering survey.
- Revegetation Cost Analysis- CDOT engineering and maintenance management has underestimated the cost and effort for project revegetation and resulting rework. This hypothesis was neither proven nor disproven due to the lack of accurate data. It is evident that a high amount of financial resources are being used for revegetation rework based on CDOT region 1 data.

This research project focused on two field investigation techniques. The first technique was the construction QC process, where five active construction sites' revegetation strategies were observed. The second technique was a forensic-based approach where revegetation success was evaluated and measured on five previous construction site areas. There were logistics, scope, and budget limitations that required the TerraLogic team to limit active construction and forensic sites to five sites each. However, based on the number and type of field observations, field measurements, and conversations with CDOT representatives, the TerraLogic team feels the conclusions formulated in this report are representative of revegetation conditions existing at most CDOT construction sites.

### *4.6.2 Common Conclusions and Themes*

This report identified numerous conclusions and recommendation to improve the success of revegetation in a cost effective way that reduces regulatory and environment risk. The observations and data collected during the construction site visits, forensic vegetative surveys, and informational survey identified some major areas for improvement. The following is a summary of those recurring themes and actions:

There is an established process for CDOT revegetation specified the CDOT "Green Book" of Standard Specifications. Based on most of the construction sites visited, there is a lack of QC within the revegetation process. Critical steps such as soil preparation, soil amendment applications, and seeding within the process are mostly not being verified by trained and knowledgeable CDOT representatives.

Contractors need better CDOT oversight and direction during crucial steps in the revegetation process. It was shown that many contractors and/or their subcontractors did not follow CDOT specifications, mostly for soil preparation and soil amendments application. There was no documentation verifying that drill seeding equipment was calibrated and seed depth penetration was according to specification. Landscape architects or qualified CDOT personnel should be providing oversight and guidance to subcontractors in the field.

The cost for not doing the revegetation project correctly the first time has been shown to be expensive and it prolongs the duration of the SCP. Information provided by Region 1 has shown non-project costs for revegetation and erosion control in the area of approximately $71,000 to $1.3 million, with several of these projects having open SCPs. As a result, CDOT maintenance takes on the SCP liability and costs for revegetation and site stabilization rework.

There is inconsistency among CDOT regions in managing the post-construction process to SCP deactivation and final site stabilization. The 70%-vegetative-cover methodology is not consistently being used by all CDOT regions for SCP. There are technical problems in the CDOT vegetative cover that can lead to bias and inaccurate results used for a formal SCP deactivation.

There is a lack of communication among many CDOT employees and contractors instrumental in the revegetation success. It appears that the landscape architect is not being fully utilized by the project engineer to answer subcontractor questions or respond to proposed specification modifications that could impact the overall revegetation strategy. Landscape architects or qualified personnel could be used for revegetation QC and to support CDOT maintenance in SCP deactivations. It was mentioned several times by CDOT personnel and subcontractors, that the project engineer does not communication well with CDOT maintenance personnel. As a result, plants undergoing revegetation have been broadcast sprayed with herbicide by CDOT maintenance as part of the routine ROW weed control.

There should be a project specific landscape design plan developed either by CDOT or approved by CDOT before construction is initiated. The current revegetation information provided in the SWMP provides some limited revegetation information about schedule, responsibilities, critical action timing, weed management, performance metrics, and monitoring. This landscape design plan would clearly identify the level of performance expected from the prime contractor and their subcontractors.

It will not be possible to immediately implement all of the recommendations provided in Section 4. It will require a coordinated effort among numerous CDOT representatives and regions to identify the recommendations that address the most overall risk to CDOT. Appendix L provides an implementation plan framework for CDOT to use and modify over time. As part of the implementation plan approach, it will be important to obtain support from upper CDOT management to execute many of the provided recommendations; therefore, it is important to find and leverage off of a program champion.

### *4.6.3 Potential Research*

Based upon the conclusions and recommendations provided in this report CDOT should consider new research projects in the following revegetation and site stabilization areas:

- Compare full project-life revegetation costs and SCP durations using the current (2014) CDOT processes to the processes and methods proposed in this report.
- Complete a cost benefit analysis comparing the resources CDOT currently uses to monitor and subsequently repair sites with SCPs open for years to the cost of hiring and inspecting proper vegetation contractors so that sites are successfully revegetated the first time.
- Identify and standardize new plant density and vegetative cover methodologies, such as those used by other agencies that fulfill CDPHE SCP deactivation requirements.
- Assess the revegetation success of site-specific native species at future construction sites versus the existing broad-based seed mixture development process.
- Compare the revegetation success on CDOT design-build projects to conventional design-bid-build projects.
- Investigate the impact of more soil testing (nutrient, organic matter, pH, and salinity) prior to construction, and more efficient methods of matching the soil amendment specifications to the specific soil qualities (identified by tests) that are lacking at each site, to avoid over or under application of amendments.
- Investigate new methods to increase knowledge and prioritization of the importance of revegetation among CDOT planners, engineers, inspectors, maintenance, contractors and others.

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# APPENDICES

# Appendix A: Literature Review and Critique of CDOT Revegetation Specifications and Process

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# Literature Review and Critique of CDOT Revegetation Specifications and Process

## Introduction

Over the past two months, the TerraLogic team of TerraLogic (Art Hirsch), Environmental Planning Group (Aaron DeJoia) and Western States Reclamation (Joe Schneider) have been focused on performing literature searches and contacting revegetation professionals within and outside the state of Colorado. The main purpose of this secondary research work was to identify a comprehensive list of revegetation test variables that will ultimately be screened and selected for study during Task 3. The following summarizes the work elements and results from Tasks 1 and 2.

### Task 1 Literature Review Summary

The TerraLogic team conducted an initial literature review of available reclamation practices and products that can potentially enhance and lead to quicker revegetation success. The team researched innovative techniques and reclamation strategies from various research references included in but not limited to the following technical sources:

- Peer-reviewed scientific journals
- BLM Gold Book
- NRCS Technical Resources
- Local seed and fertilizer vendors
- Past CDOT Revegetation Research
- CDOT Green Book Specifications
- American Society of Mining Reclamation
- High Elevation Revegetation Proceedings
- USDA Plant Material Centers Publications
- Colorado State University and University of Wyoming (Reclamation and Restoration Center)

The goal of the Task 1 Literature Review was to identify and evaluate emerging trends, innovative products and techniques, and proven manageable variables that both enhance revegetation success and are cost effective.

Revegetation test variables include specific plant biological, and soil characteristics, and the potential interactions between these variables. Strategies to enhance and modify these plant, biological and soil variables and associated implementation strategies were considered for field testing due to their potential to increase reclamation success. Revegetation variables were reviewed so that both current and potential future practices can potentially be evaluated in the field trials.

The second component of the Task 1 Literature Review was to review and evaluate other state departments of transportation (DOTs) and other state agencies responsible for creating and implementing revegetation guidelines. The TerraLogic team contacted and surveyed other states' key DOT personnel to determine what they consider effective and ineffective revegetation variables and practices.

The third component of the Task 1 Literature Review was to conduct interviews with key CDOT personnel who are familiar with CDOT's revegetation process. These personnel were identified by the

CDOT project manager. These interviews were conducted to determine current CDOT revegetation practices and which revegetation practices are working and not working.

Table 1 provides a listing of CDOT and regional state DOT contracts.

Task 2 Review and Critique of the Existing CDOT Revegetation Specifications, Processes, Studies and Guidelines Summary

Concurrent with Task 1, the TerraLogic team reviewed and evaluated the current CDOT specifications, processes, and guidelines for construction site revegetation. The purpose of Task 2 was to establish a baseline reference point to evaluate new and innovative approaches and revegetation strategies. The evaluation was performed using the following actions:

- CDOT specifications were critically reviewed and critiqued by the TerraLogic team member, Western States Reclamation, in light of their experience and practical application of the specifications.
- In coordination with the CDOT project manager, the CDOT Landscape Manager, Mike Banovich, and regional CDOT representatives, the TerraLogic team will visit selected construction sites to evaluate the challenges and level of implementation of CDOT specifications by contractors; this action (not yet completed) will complement the existing CDOT contractor specification monitoring program.
- Revegetation specifications and guidance from DOTs within the Intermountain West having similar climatic conditions (arid, semi-arid and mountain conditions) were reviewed based on telephone conversations and assessed against the existing CDOT specifications.

The information obtained from Tasks 1 and 2 were compiled and summarized in Table 2. Table 2 contains and summarizes information obtained from research-based literature review and information obtained from both CDOT and regional state DOT references.

**Summary of Collected Task 1 and 2 Information**

The TerraLogic team contacted 20 CDOT employees and 7 regional state DOT revegetation-landscaping professionals. There were some consistent points of view associated with revegetation challenges and successes. The following summarizes the main areas of discussion that were generally consistent among some of the interviewed professionals.

Regional DOT Landscaping Professionals

Regional DOT landscape professionals were contacted by the TerraLogic team. It was envisioned that these sources would be good source of information since regional state DOTs have similar climatic conditions and revegetation challenges as Colorado. The regional DOTs landscaping professionals were from six states including New Mexico, Nebraska, Kansas, Utah, and Wyoming.

There was a consistent list of questions and discussion topics that were used by the TerraLogic team when interviewing the state DOT representatives. The discussions were meant not to be very structured and were meant to be more interactive in nature. The phone interviews generally lasted 30-60 minutes. The main areas of discussion involved the following topics and questions:

- What revegetation practices are working well on projects?
- What DOT and/or contractor challenges are affecting project revegetation (e.g. what actions are not working well)?
- Challenges with their revegetation specifications and design engineers, if any?

- What type of contractor monitoring is being performed during revegetation, if any?
- What type of research projects are being conducted, if any?

The following summarizes some of the basic themes and responses from the interviews:

- Most all state DOT representatives mentioned the challenges of revegetation due to drought conditions; none of them were a proponent of irrigation due to costs and poor results.
- Regional DOTs representatives recognized the need for additional resources to watch contractors during critical times such as planting and plant establishment; specification compliance is a problem.
- Some DOTs are doing small research projects on soil amendments, such a bio-sol, that are more observational than quantitative.
- Certification or pre-qualification of revegetation contractors would be advantageous to revegetation success.
- Native plants take longer to establish than non-natives, which adds to the long term cost and stormwater permit duration.
- It is difficult to coordinate and plan revegetation expectations during the planning process with contractors and sometimes with design engineers.
- High risk revegetation contractors are known and monitored whenever possible in the field.
- It is hard to make contractors responsible for complete and successful site revegetation due to contracting constraints.
- Very few DOTs use soil testing before construction to assess amendment needs but recognize the need for soil testing; some are uncertain about the soil testing methodology.
- There needs to be better communication with herbicide sprayers who impact revegetation growth.

CDOT Landscaping Professionals, Water Pollution Control Managers and Study Panel members
There was a consistent list of questions and discussion topics that were used by the TerraLogic team when interviewing CDOT representatives. The CDOT representatives were identified by the CDOT project manager such as regional water pollution control managers (WPCM), project study panel members, landscape architects, maintenance professionals, and some regional planning and environmental managers. The CDOT discussions were meant not to be very structured and were meant to be interactive. The interviews generally lasted between 60-90 minutes in person or over the telephone. The main areas of discussion involved the following topics and questions:

- What revegetation practices are working well on projects?
- What CDOT and/or contractor challenges are affecting project revegetation (e.g. what actions are not working well)?
- What type of contractor monitoring is being performed during revegetation, if any?
- What type of specification changes would you like to see if any?

The following summarizes some of the basic responses:

- Most interviewed CDOT professionals think that contractors are not consistently following CDOT Green Book Specifications.
- Most CDOT representatives mentioned the lack of available resources for monitoring contractors during revegetation.
- There is no real identified responsibility in the field to coordinate, oversee, and monitor the contractor during actual soil preparation, seeding, and vegetative establishment before handing off the project to CDOT maintenance.
- There needs to be revegetation training for the CDOT project engineers and/or Regional WPCMs.
- The seed mixture is perhaps too broad and not project site specific; using an eco-zone selection approach could improve vegetation establishment.
- There are inconsistencies on how percent-vegetative cover is calculated before and after construction to achieve 70% vegetative cover.
- There could be better site specific reclamation plans that should be developed by the contractor within the SWMP.
- Soil amendments based on soil type and soil chemistry can be cost effective.
- A contractor escrow fund should be considered to ensure revegetation occurs before their complete departure from the project.
- Revegetation is an afterthought by contractors and some project engineers who are anxious to move onto the next project.

### CDOT Green Book Revegetation Specification Critique

Colorado Department of Transportation (CDOT) Standard Specifications for Road and Bridge Construction 2011 (the current "Green Book") covers basic and conventional revegetation practices for Colorado contract work awarded by CDOT. Based on the TerraLogic team's overall revegetation experience, we are aware that more detailed information is typically provided beyond the Green Book on project plan sheets and within project special provisions. This CDOT approach appears to be sufficient as a project foundation and provides CDOT the opportunity to custom design the revegetation scope of work. Four sections of the Green Book relating to revegetation practices were reviewed and examined for this technical memorandum. Feedback on additional standards and practices that have a high potential to increase the likelihood of revegetation success is provided by the TerraLogic team.

#### Specification Section 207 Topsoil

This section references the handling and placing of topsoil material on CDOT projects. Soil is a critical element in the establishment of plants and this section would benefit from additional language regarding the methodology for proper topsoil identification, salvage, storage, and placement. A list of suggested project specifications and design guidelines changes or modifications is included, based on the TerraLogic team's field experience:

- Require a pre-disturbance topsoil depth determination, soil sample, and nutrient analysis. Topsoil should be sampled 21 days prior to the start of construction to allow sufficient time for laboratory processing and analysis. Soils should first be determined using published Soil Survey information, then documented using a pre-disturbance topsoil soil survey in the field, and appropriate soil samples should be collected. Stripping depths and locations should be determined by soil analysis results and on-site inspections. All topsoil documentation and review should be conducted and signed under the supervision of a Certified Professional Soil Scientist (CPSS) as administered under the Soil Science Society of America.

- Currently there are no CDOT standards for identifying suitable seedbed quality material (topsoil) prior to initiation of construction activities. The practice of using soil surveys to identify the quality and quantity of topsoil for use in revegetation has been utilized by the mining industry for nearly 40 years. The oil and gas industry is now facing the requirement of identifying and salvaging topsoil for use in reclamation efforts. The costs of conducting a pre-disturbance soil survey and topsoil management plan will be offset by adding correct soil amendments to only soil materials which potentially lack favorable seedbed quality material. Also, management of topsoil resources will reduce failed revegetation maintenance and monitoring costs. Pre-construction soil analysis and survey are necessary because often CDOT disturbances take place in areas of previously disturbed right of way conditions, which make the NRCS soil survey data of minimal use.

- Field identification of topsoil material and stripping depth is important for increasing reclamation success. Soil survey information is now electronically available from multiple sources including the Web Soil Survey (WSS), SoilWeb, and GIS-based Shape Files. SoilWeb is also available as an application for both Android and I-devices. The electronic data generally contains soil mapping units at the Order 2 and Order 3 mapping level which can be used for making soil management decisions. Order 2 and Order 3 soil maps represent soil mapping units that are delineated as soil series, soil complexes, and soil associations. The smallest delineation for Order 2 soil map units is approximately 4 acres while Order 3 soil mapping units can only be delineated to approximately 10 to 16 acres by utilizing electronic soil survey information. Existing Order 2 or 3 soil mapping could be overlaid on construction maps utilizing GIS methods to assist in making better construction and reclamation decisions. In addition, soil sampling intensity could then be defined based on the construction and soil information combined. Laboratory analysis for the soil samples could be utilized to rate soils as Good, Fair, or poor for use as seedbed material and to determine soil amendments requirements and rates. Topsoil volume mass balance can then be calculated to determine topsoil replacements depths for the project.

- Topsoil Section 207 would benefit from further discussion on the importance of maintaining segregated topsoil stockpiles throughout construction. Co-mingling of topsoil with other non-suitable on-site soils greatly depreciates or destroys this resource.

- Topsoil Section 207 could benefit from language restricting topsoil salvage in unfavorable conditions, such as soil moisture conditions that are too dry or too wet. If topsoil is salvaged in unfavorable conditions, it could lead to permanently damaging beneficial soil structures and composition.

- The identification and use of suitable subsoil materials should be incorporated into the specifications and designs. Utilizing quality subsoils could increase project success and reduce overall project costs. Quality subsoil conditions would have to be identified in the field by a soil scientist and confirmed with soil testing and analysis.

- Ensure that the stripping and stockpiling of available topsoil is executed properly by having on-site inspections by trained personnel. Additional inspections would have to be made throughout the duration of the project to make sure salvaged soils are being stored properly.

- Destroying soil stockpiles or SWMP BMPs during earthwork activities is not acceptable and should be enforced in the project specifications and by penalty when necessary. If available topsoil is identified, but is not properly salvaged or stored, the contractor should be responsible for importing quality topsoil or adding additional amendments without cost to CDOT. In order for this system to work a topsoil salvaging, stockpiling, and placement plan would have to be designed and enforced by qualified personnel. Documentation of topsoil handling, storage locations, and storage volumes would be critical to enforce any type of penalty system.

- Proper equipment and tools should be used for topsoil placement. For example, heavy equipment can cause soil compaction, which hinders root growth and plant development.

Specification Section 208 Erosion Control

This specification section is directed toward temporary BMP installation, inspection, maintenance, and removal rather than establishment and proper placement of long term BMPs. It would be beneficial for CDOT projects to involve revegetation contractors in the on-site environmental pre-construction conference. At this meeting project issues and constraints, in regards to successful revegetation could be identified and discussed amongst the project group. An early on-site meeting would also give the SWMP designer the opportunity to meet the revegetation contractor and discuss the project. Soil stripping, stockpiling, placing, and preparation could also be discussed at this meeting. Having this discussion would get everyone on the same level of understanding, and would give the revegetation contractor the opportunity to identify problem areas, evaluate soils, and existing vegetation prior to mobilizing. Getting the revegetation contractor involved in the process would be beneficial if it was an experienced and reputable company.

At the project walk-through and throughout the duration of the project, it is recommended that the permanent BMPs be inspected with the temporary BMPs by qualified/trained personnel for adherence to the specifications. Inspections throughout the duration of the project could provide valuable information to the project team, leading to adjustments in the revegetation approach. This would also provide the opportunity for the project team to discover poor workmanship, and have the revegetation contractor correct the work before the project is handed over to CDOT maintenance.

Specification Section 212 Seeding, Fertilizer Soil Conditioner and Sodding

Overall, these specifications cover basic regional revegetation practices and include discussions on timing, materials and standard rates. Additional revegetation information and design such as amendment rates and project specific seed mixes is typically provided on project plans. Listed below are topics that should be considered for incorporation into project planning and or specification Section 212:

- The use of qualified contractors to perform revegetation would increase project success. The specifications have language directed towards the use of proper reclamation equipment, but the use of qualified personnel trained on proper reclamation equipment is also a critical factor in project success.

- If proper soil testing and analyses were utilized, soil amendments would be decreased based on topsoil chemistry. Thus, up-front soil sampling expenses will reduce the cost of unnecessary amendments and provide a better native soil medium to increase vegetation establishment and success. Proper enforcement of topsoil handling and placement would play a key role in the success of topsoil salvaging and testing.

- Amendment type and associated application methods should be considered when recommendations are identified by a soil scientist and or CDOT landscaping professional. In some cases, a topical application may be advantageous in contrast to the specified incorporation depth of 4” or 6”. Boilerplate soil amendment recommendations should be avoided within the SWMP reclamation plan, since, since this could lead to over or under application of amendments.

    - Fertilizers – Best used as a topical application to allow nutrients to move through the soil profile.

  - Humates – Best used as a topical application
  - Mycorrhizae – Best applied next to seed (In a hydro seed slurry or with seed mix)

- The use of soils amendments needs to be based on soils test results including organic matter content, N-P-K, electrical conductivity, soluble ions, pH, sodium absorption percentage, and percent of calcium carbonates.

- It is very difficult to get standard agricultural equipment on 2:1 slopes to drill seed. A 2.5:1 slope should be the maximum slope for drill seeding and straw mulching. Drill seeding should not be accomplished on slopes steeper than 2.5:1 or anytime a seed drill has a tendency to slide down the slope while be towed behind a tractor. This results in improper seed placement.

- Compaction is a major problem and needs to be addressed in the specifications and enforced in the field by trained personnel. Compacted areas should be ripped or tilled prior to topsoil placement and seed bed preparation.

- Soil preparation as a required two-step process for tillage would improve seed bed specifications. Most times, ripping the soil surface only once is not adequate, and contractors often bid to do it just once. As a pay line item soil ripping per acre per pass might get better soil preparation and overall reclamation success.

- Current seed plans appear to be based on regional vegetation zones or ecosystem communities. This practice may be too general to determine the appropriate seed mixture that should be utilized for site-specific vegetation communities. Often times, there is adequate information on electronic soil survey to determine vegetation typical of a soil mapping unit; however, performing a baseline species inventory to determine the existing vegetation communities on site is more desirable. The existing plant communities are already adapted to local site conditions and have a greater likelihood of survival following construction activities.

- A review of several seed mixtures indicates that there has not been consideration for balancing the drill seed rate to an average of 50-60 seeds per square foot, which is an accepted standard in the western United States. There does not seem to be consideration given to balancing individual plant species in a seed mixture based on aggressiveness, difficulty in species establishment, seeds per pound, etc. The reviewed seed mixtures contained anywhere from 77 to 657 seeds per square foot. Distributing too few or too many seeds can be detrimental to plant establishment. An overabundance of seeds per square foot can lead to intense competition for water and nutrients that may not be available in the soil. This could negatively affect stand diversity or lead to eventual die off of the vegetation community.

### Specification 213-Mulching

The mulching specification section covers basic mulching materials, methods, and practices. This section appears to provide adequate guidelines for contractors to follow; however, a few additions and corrections could make this section better. Inspection of material quantity and quality is critical when it comes to achieving proper coverage during mulching operations. Enforcement of crimping depth, straw/hay mulch length and overall quality of materials used would greatly increase the effectiveness of mulching on revegetation projects.

- Description of proper crimping depth and equipment would give the inspectors something to enforce when performing and enforcing inspections. A crimped mulch should be firmly anchored into the soil. In some cases this might be 1 inch; in other cases it might be 2.5 inches.

- Contractor must utilize a straw product that is no less than 6 inches in length in order to achieve proper crimping.

- Keeping up to date approved product lists would prevent substandard products from being used on CDOT projects.

The above four sections of the CDOT Green Book have a foundation of specifications that should lead to project success, if properly inspected and enforced. There are some adjustments to the specifications that could be made that would help improve the current specifications and perhaps lead to greater project success. The addition of science-driven project special provisions and plans derived from on-site sampling and observation is critical to revegetation success and cost effectiveness.

**General Revegetation Recommendations**

Using the information collected during Tasks 1 and 2, the TerraLogic teams has compiled a listing of recommendations based on the observation and implementation of the CDOT revegetation process and information collected from numerous CDOT representatives. As articulated during the July 29, 2013 study panel meeting, the main barrier facing CDOT regarding effective revegetation is the current CDOT revegetation implementation process (70% vegetative cover from baseline conditions) from contracting to final stormwater permit closure. Although researching new technologies and materials is important, the TerraLogic team feels it is equally, if not more, important for CDOT to identify gaps of effectiveness in the overall revegetation process. Not specifically identified within the scope of work under this research project, TerraLogic feels it is necessary to identify revegetation process recommendations that may go beyond the Green Book specifications. Some of these recommendations can be tested as part of a study project while some recommendations are not amenable to effective research approaches. The following are the TerraLogic team's revegetation recommendations for CDOT consideration:

- CDOT should consider using their Water Quality Training Program to develop 1-2 training modules on effective revegetation techniques; the training program should be focused to the CDOT project engineer and regional WPCM.

- CDOT should have direct oversight of the contractor revegetation activities, especially during certain critical times such as seeding. Some CDOT regions use their regional WPCM only for contractor erosion control and ignore the revegetation specifications, while some regional WPCM do both types of oversight. There needs to be consistency in contractor oversight either by designed landscaping professionals or regional WPCMs.

- There should be improved contractor oversight prior to and during seeding and mulching. Proper soil preparation such as soil ripping and seedbed preparation and technically based amendments should be verified by CDOT before seeding commences.

- There should be a discussion early in the project regarding the technical approach and CDOT expectations about the proposed revegetation plan developed by the contractor within the CDOT SWMP manual; the revegetation plan should be more detailed within the CDOT SWMP (goals, objectives, actions and strategies, performance measures, monitoring, corrective actions, responsibilities).

- There should be a CDOT representative present during seeding to direct and answer questions from the contractor; this will avoid the potential of the contractor short circuiting the CDOT revegetation process.

- CDOT should consider having a revegetation certification process in which only qualified contractors can be used on CDOT projects.

- There should be consistent interpretation, understanding and measurement of the percent-vegetative ground cover; it is possible that the background measurements could be overestimated by counting non-native or noxious weeds in the calculations.

- The revegetation process should be monitored at least annually to identify potential revegetation problems and the need for re-seeding or other corrective actions.
- High risk revegetation contractors should be identified and closely monitored for specification and process compliance.
- Provide financial incentives to contractors to achieve 70% vegetative cover perhaps using annual milestone requirements or other performance measures; this action could be a very cost effective incentive to contractors.
- Proper topsoil management is important especially when imported topsoil is not allowed by CDOT and the quality of existing soil is unknown.
- Evaluate each CDOT region's eco-zones and project specific plant species to evaluate seed selection.
- Identify creative contract vehicles or mechanisms that place more responsibility on contractors for revegetation success.
- Develop project specials and plans that complement the Green Book specifications and give the designer the opportunity to customize the revegetation process. Stay away from boilerplate solutions as much as possible. This would allow for the application of alternative revegetation practices such as soil pitting or the addition of custom soil amendments for challenging sites.
- Have topsoil sampling, analysis, and planning, which is should be performed preferably under the supervision of a Certified Professional Soil Scientist, as a requirement in plans or specifications.
- If soil amendments are specified, make sure the most effective application of the amendments is spelled out in the project specifications or revegetation plans.
- Conduct periodic monitoring of seedling density and plant establishment on the project, and keep records of data for future reference.
- Seed mix design and inspection should be performed by a qualified revegetation contractor.

**Revegetation Cost Effectiveness**

It has been demonstrated by research based studies that it is very cost effective to perform site revegetation (reclamation) correctly the first time as opposed to revegetating after plant failure. Western States Reclamation's David Chenoweth developed a paper entitled "*The Economic Benefits of Completing Reclamation Successfully The First Time for Oil and Gas Cites*" for the International Erosion Control Association (February 18, 2010). This paper is provided as Attachment A. It was determined that for oil and gas well sites, over 50% cost increases over initial revegetation cost, equating to an additional $20,000-$40,000 can result for revegetation sites that failed. This cost does not account for additional environmental management and consultant costs, and potential stormwater fines. The direct costs associated with revegetation failures include the following:

- Retrieving sediment that has mobilized off site
- Replacing sediment in washout areas/replacement of lost topsoil
- Re-grading
- Re-seeding

- Replacement of impacted BMPs
- Extending the duration of weed management activities
- Additional maintenance costs

It was determined that for oil and gas facilities, the most common revegetation failures are associated with three factors; the lack of available, quality topsoil, the lack of implementing stormwater best management practices (BMPs) and the lack of clear, upfront revegetation design and follow up performance supervision. The critical factors for successful revegetation include the following:

- Initial planning and site surveys
- Topsoil placement and re-grading
- Seed mixture design
- Seeding methods
- Mulch and erosion-control fabrics
- Stormwater BMPs
- Proper maintenance and monitoring

Many of these issues are previously discussed above in TerraLogic team's revegetation recommendations.

**Table 1**
**Main Phone Contact List**
Innovative Revegetation Study (July 26, 2013)

| | |
|---|---|
| Kansas: Jason Van Nice - 785-368-7263 | Contacted |
| Kansas -Scott Shields -785-296-4149 | Contacted |
| CALTRANS - 916-654-5266 | Contacted |
| Utah - Terry Johnson 801-633-1327 | Contacted |
| Andrew Stecklein –R2-719-227-3264 | Contacted |
| Steve Mulqueen - 303-757-9138 | Not Contacted originally, contacted later |
| Gary Spinuzzi – R3- 970-683-6254 | Left messages |
| Mike Vanderhoof-R3 | Left Message |
| Chuck Attardo-R1 | Contacted |
| Michael Doyle – R1-720-497-6917 | Not Contacted |
| Jennifer Klaetsch –R3-303-757-9481 | Contacted |
| James Walker –Maintenance (303)512-5506 | Contacted |
| Tyler Weldon -Maintenance(303)512-5503 | Contacted |
| Jennifer Gorek –R4- 970-350-2264 | Contacted |

| | |
|---|---|
| Mike Banovich EPB | Contacted |
| Fran Mallonnee R5 | Contacted |
| John Samson-Wyoming | Contacted |
| William Hutchinson- New Mexico | Contacted |
| Ron Poe-Nebraska | Contacted |
| Susie Hagie-R1 | Information received from 4/11/13 memo to Bryan |
| Belinda Arbogast R1 | Contacted |
| Tripp Minges-EPB | Contacted |
| Tom Boyce-EBP | Contacted |
| Sonya Erickson-R2 | Contacted |
| Lisa Streisfeld-R2 | Contacted |
| Cliff Corwin-R1 CDOT Maintenance | Contacted |
| David Weider-CDOT Maintenance Superintendent | Email exchange |
| Phillip Anderle R 4 Maintenance | Contacted |
| Ed Gentry R4 Maintenance | Contacted |

# Appendix B: Alternative Analysis of Potential Research Variables (Tables B-1 through B-4)

Available on Final Report Appendices CD.

# Appendix C

## Appendix C: Field Testing and Methodology Plan and Construction Revegetation Quality Control Checklist Tool

# Final
# Field Testing and Methodology Plan

# Innovative Vegetation Practices for Construction Sites
## (Innovative Revegetation Project)

Colorado Department of Transportation
Department of Transportation Development Applied Research and Innovation Branch

TerraLogic
Environmental Planning Group
Western States Reclamation

October 25, 2013

# Appendix C

## Research Plan Abstract

Identification and testing of critical revegetation variables is an import process to determine which variables could increase revegetation rate and success. The TerraLogic team identified revegetation variables that have been shown as important for revegetation success. The identification of major critical revegetation variables was conducted during the literature review process (Task 1/2). Once the potential variables were identified through the literature review process, an alternatives analysis was conducted to select the most promising revegetation variables that will be tested in the field trials.

The alternatives analysis was a straight forward process that obtained input from the CDOT project manager and study panel members. Revegetation variable identification began during the literature review process. At the end of Task 1 and 2 the universe of potential variables was identified. The TerraLogic team ranked the variables based on revegetation founded criteria. The TerraLogic team then worked with the CDOT project manager and study panel members to finalize the selection of research variables that will be evaluated during the field trials.

The alternatives analysis was conducted on selected variables that are relevant to the Colorado environment, and have the potential to enhance CDOT's revegetation practices. The alternatives analysis identified 12 different treatment variables that were evaluated for ultimate field study. Based on the criteria below, 3 three research variables were selected

- Availability
- Cost
- Sustainability
- Proven within other locations
- Scientific validity
- Practicality
- Statewide application
- Resource consumption

At the conclusion of the alternatives analysis (Task 3) the TerraLogic team developed this Field Testing and Methodology Plan to accurately test the selected research test variables. This plan will be developed and implemented by the TerraLogic team to obtain the goals and objectives of the Innovative Revegetation Project.

# Appendix C

## Final
## Innovative Revegetation
## Field Testing and Methodology Plan

### 1.0 Introduction

The research variables selected for field study under the Innovative Vegetation Practices for Construction Sites (Innovative Revegetation Project) was a result of an extensive alternative analysis that involved both the CDOT study panel and the TerraLogic team. The selected research variables (tasks), which are now called research tasks, complement the stated goals and objectives of the overall research study:

- Identify and test a series of revegetation variables that upon utilization will reduce the revegetation/stabilization time necessary to deactivate the CDPHE construction stormwater permit
- Reduce the CDOT financial and professional resources for stabilization management
- Identify practices that can be of immediate use to CDOT statewide
- Reduce CDOT overall construction stormwater risk and liability

The selected research tasks for the Innovative Revegetation Project include:

- Salvage Soil Management- The working hypothesis is that improved plant revegetation can be achieved if nutrient and organic amendment concentrations of topsoil are known. Instead of using template nutrient and organic amendments to salvaged topsoils, better growth and cost effectiveness can be achieved by adding only what nutrient/amendments are *actually* needed to promote effective revegetation. Analytical soil testing will be performed at active construction sites to assess nutrient/amendment needs and identify cost savings.
- Construction Revegetation Quality Control- The working hypothesis is that the CDOT revegetation process is not being followed; and therefore the lack of compliance is negatively affecting the rate and quality of revegetation. Field quality control (QC) evaluations using a field revegetation checklist at active CDOT construction projects will be used to assess process compliance and gaps. This hypothesis is based on information gathered during Task 1 and 2 of the Innovative Revegetation Project (See Attachment 1).
- Forensic Revegetation Analysis- The working hypothesis is that improved revegetation will occur if Contractors follow specifications and contract requirements. The project will go to former construction sites throughout different eco-regions and review and evaluate reclamation efforts and performance. These project sites have followed CDOT revegetation specifications or have well documented revegetation methods according to CDOT representatives. The Innovative Revegetation Project will determine what revegetation elements have worked and what have failed at selected sites throughout Colorado.

### 2.0 Research Variable Alternative Analysis Screening Process

Tasks 1 and 2 were involved with performing secondary research on new and innovative ways to revegetate construction sites. The purpose of this type of literature search and informational gathering was to identify the “universe” of potential test variables for field research studies. To this end, the TerraLogic team identified and compiled over 50 potential research variables that were associated with the CDOT revegetation (Attachment 2).

# Appendix C

These potential revegetation research variables fall into two basic categories; CDOT revegetation process and research based technical soil chemistry to plant relationships. The test variables that were developed and considered by the TerraLogic team were obtained from professional literature, conversations with CDOT professionals and DOT landscape professionals from neighboring states (Attachment 1).

The second part of the alternative analysis involved the TerraLogic team presenting the "universe" of potential research variables to the CDOT study panel. The study panel members were asked to each select their top five research variables for field study. In addition, each of the TerraLogic team members also selected their top 5 research variables.

The third step involved the TerraLogic team consolidating the CDOT study panel priority variables to the top 12 research variables for field study. The TerraLogic team then independently prioritized the top five potential research variables and provided CDOT field study recommendations (Attachment 3). The criteria used by TerraLogic to select the top five involved the following:

- Availability
- Cost
- Sustainability
- Proven within other locations
- Scientific validity
- Practicality
- Statewide application
- Resource consumption

The last step involved a CDOT study panel meeting in which TerraLogic discussed in detail the top 12 research variables and their top five recommendations. TerraLogic provided rough costs estimates for each of the top five research variables. The CDOT study panel was asked to use all the accumulated information and recommendations to select the final three research variables that will be field tested by the TerraLogic team.

The following discusses in detail the proposed Innovative Revegetation Project's Field Testing and Methodology Plan (the Plan). It identifies the process and test methodologies that will be taken by the TerraLogic team and CDOT representatives for the three selected research tasks:

1. Construction revegetation quality control
2. Salvage soil testing and analysis
3. Forensic revegetation analysis

## 3.0 Construction Revegetation Quality Control

Quality control is a critical element in any process orientated activity; it is the fundamental component of continuous process improvement. Quality control ensures product reliability, sustainability, and maintenance of high quality. The process of quality control within the revegetation context is to outline the CDOT process, identify quality actions (specifications) and identify verification elements (see Attachment 4). These verification elements are the most critical links in the process and need to be visually verified to ensure overall process quality.

Based on the information gathered in Tasks 1 and 2 and summarized in the Task 2 Technical Memorandum, the working hypothesis is that the CDOT revegetation process is not being followed, and a lack of compliance is affecting the rate and quality of revegetation. If this hypothesis is true, significant amount of resources, time, and money, are being inefficiently used to revegetate project locations, and an unnecessary amount of environmental liability is being managed by CDOT maintenance.

# Appendix C

A process based quality control approach will be used on existing-active construction sites that will be performing revegetation actions. A formalized Construction QC Revegetation Checklist will be used by the TerraLogic team to evaluate and document compliance with CDOT specifications.

The CDOT study panel technical leader, Mike Banovich, has selected active construction sites for QC analysis. The TerraLogic team will coordinate with CDOT representatives to visit active construction sites through the construction and revegetation phases of the projects.

Field Quality Control Approach

The following is the process that will be used by the TerraLogic team on performing and assessing CDOT Construction Revegetation Actions for the Innovative Research Project:

1. Selection of Active Construction Projects- CDOT has selected five active construction projects that will involve at a maximum of three site visits each during construction-site revegetation. The sites that were selected were based on construction project complexity and diversity, CDOT regions, revegetation challenges, and project willingness for participation in the QC process. Table 1 provides a summary of the active construction sites that will be visited by the TerraLogic team. If the study panel determines that different project sites better meet the goals of this project, sites may be substituted so long this does not significantly alter costs, e.g. extended travel times. TerraLogic will periodically communicate with the technical leader, Mike Banovich, regarding any site changes.

2. Development of Field Construction QC Checklist- a field construction QC checklist has been developed that will used as a tool to assess revegetation compliance to CDOT specifications and recommended procedural changes identified in the Task 2 Technical Memorandum (Attachment 4). This checklist tool will be used and refined during the QC process such that a final revegetation QC tool can be developed as a final deliverable for this project. The checklist contains control actions that are from CDOT specifications and those identified as recommendations in Task 2 Technical Memorandum. It is envisioned that this tool will be used by project engineers, maintenance representatives, landscape professionals and regional water pollution control managers (WPCM) for construction-revegetation projects.

3. Site Visits to Construction Sites- there will be a maximum of three site QC visits performed by the TerraLogic team for each identified site. The team will attempt to visit the site at critical times and stages in the revegetation process identified as Verification Points in the Field QC Checklist. These Verification Points include control action such as but not limited to seed selection, soil amendment addition, seeding application, mulch application, and plant growth monitoring, etc. During the field QC studies, soil samples from surface soils and/or salvaged soil piles will be collected (see Section 4.0). The TerraLogic team may collect additional soil samples within the Project area or within a reference site. The site visits will be coordinated by the CDOT study panel technical lead or his designee to allow TerraLogic team site access. The TerraLogic team may ask the project engineer or contractor for specific information and documentation to verify quality control actions.

4. Results Compilation and Analysis- an Excel database will be developed for all the visited construction projects visited during the field QC study. The database will be reviewed and assessed for QC compliance, process gaps, and potential CDOT specifications or actions that provide limited or no value to the revegetation process. The results and analysis of the overall QC field study will be provided in the final research report. For project confidentiality, the final report will not mention the actual project name or the project engineer; the project location may be identified in the report if it is relevant to the research findings, but anonymity will be preserved where possible.

5. Follow Up Construction QC Info & Survey- The CDOT study panel anticipates a potential need for the TerraLogic team to obtain additional information or documentation from the project engineer or contractor, after the field visits are complete. This may include confirmation of results documented via observation; comparison of

survey answers vs. actual observations; or new questions raised by the QC process, or other. If there are consistent questions that need to be asked to all project engineers, a process such as a web-based survey (Survey Monkey) may be used to obtain necessary information or specific questions may be asked to specific projects via the CDOT Project Technical Lead to the project engineer(s).

6. Project QC Documentation- Completed Field Revegetation QC Checklists along with photo-documentation, project notes and correspondences will be part of the project file and given to CDOT at the end of the project. Results will also be described and discussed in the final report. It is important to mention that the information gained from this field QC study may be used by CDOT to develop a statewide revegetation survey to project engineers and maintenance and environmental representatives for a future study.

Table 1
Construction QC Revegetation Locations

| Project | Location/CDOT Region | Project Delivery | Project Type |
|---|---|---|---|
| Southern Urban Foothills | Region 2 | Design-Build | Lane addition |
| Eastern Plains | Region 4 | Bid-Build | Lane and bridge addition |
| East Urban Metro | Region 1 | Bid-Build | Lane and bridge addition |
| Mountain Corridor | Region 3 | Bid-Build | Interchange |
| Urban Corridor | Region 1 | Design-Build | Lane and Bridges- large corridor project |

## 4.0 Salvage Soil Testing and Analysis

The objective of the salvage soil and testing task is to determine if topsoil salvage can be used to decrease total reclamation costs and improve soil conditions to enhance reclamation success. Soil testing will be conducted at active construction sites with varying on-site topsoil salvage strategies and conditions including:

- No topsoil salvage (0 to 18 inches)
- Uniform pre-defined topsoil salvage depths (0 to 6 inches)
- NRCS soil survey topsoil salvage depths
- Field verified topsoil salvage depths

### Working Hypothesis

- Salvaging topsoil from the ROW prior to construction at the correct depth will decrease overall revegetation costs.
- Prior to construction, salvaging topsoil at the correct depth from the ROW will improve seed bed soil chemistry and provide improved conditions for revegetation success.

# Appendix C

Overview of Field Task Approach

The team will visit construction sites to collect topsoil samples for laboratory analysis and evaluate topsoil salvage techniques. At each site, the TerraLogic team will collect samples that represent the no salvage, uniform salvage, NRCS salvage, and field verified salvage methodologies. During the site visit the team will collect soil samples as described below for *each* topsoil salvage methodology (Figure 1):

- **No Salvage Alternative Sample-** These samples will represent the no salvage alternative. Upon review of the each identified site, the TerraLogic team will identify how and if topsoil was salvaged. If it is determined that topsoil was not salvaged, soil samples will be obtained from the mixed (topsoil and subsoil) soil stockpiles identified (Figure 1). From the identified mixed soil stockpiles five grab samples will be obtained and placed in a plastic bucket. Once all the subsamples are collected the collected soil will be thoroughly mixed and approximately one gallon of material will be placed in a plastic bag and delivered to the laboratory for analysis.

  In areas where topsoil salvage was performed, or construction has not been started, or soil has been replaced, soil samples will be collected from undisturbed areas within the ROW (Figure 1). Within the undisturbed areas five to ten subsamples will be collected using a handheld soil probe to a depth of 18 inches and composited. Once all the subsamples are collected the soil will be thoroughly mixed and approximately one gallon of material will be placed in a plastic bag and delivered to the laboratory for analysis. These samples will provide an estimate of the soil chemistry for topsoil mixed with subsoil from the project site.

  If soil stockpiles exist, and it is confirmed that topsoil salvage was not performed, composite soil samples will be obtained from the stockpiled soils. If correct soil stockpiling has occurred, and the team cannot confirm topsoil salvage methodology, then samples (0-18 inches) will be obtained from non-disturbed surface soil areas within the project area ROW.

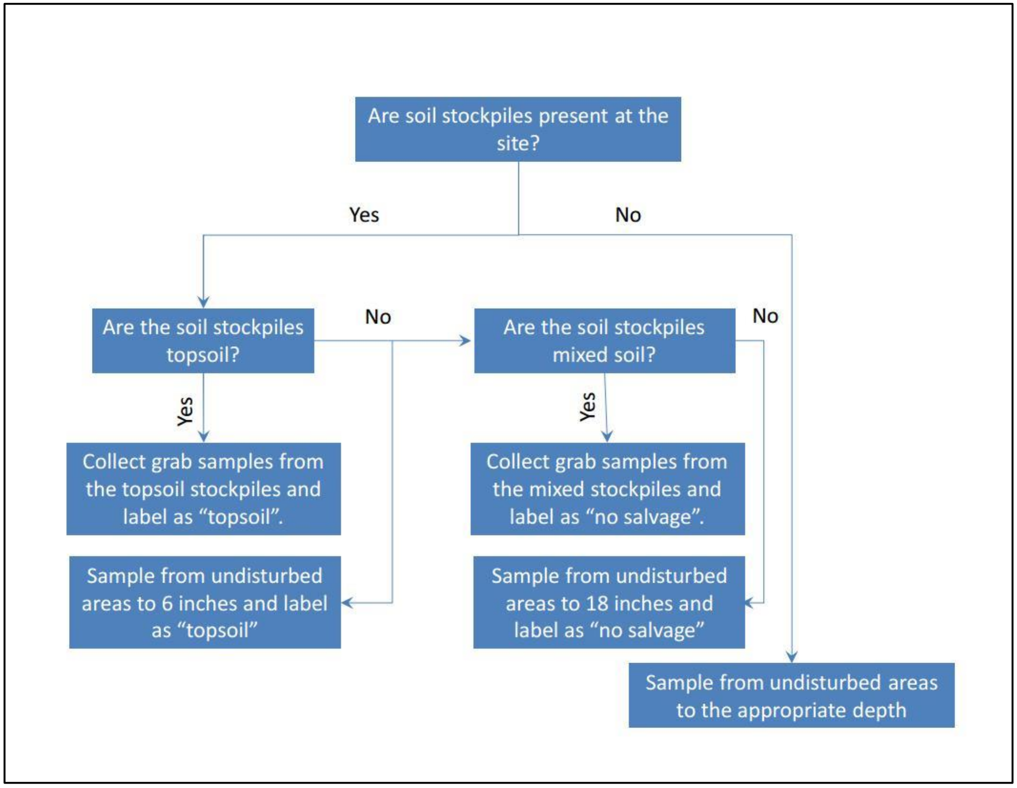
- **Uniform Topsoil Salvage Sample-** Upon review of the each identified site the TerraLogic team will identify how, and if, topsoil was salvaged. If it is determined that topsoil was salvaged according to CDOT specifications, soil samples will be obtained from the identified topsoil stockpiles located on the site (Figure 1). From the identified topsoil stockpiles five grab samples will be obtained and placed in a plastic bucket. Once all the subsamples are collected the soil will be thoroughly mixed, and approximately one gallon of material will be placed in a plastic bag and delivered to the laboratory for analysis.

  In areas where topsoil salvage was not performed according to CDOT specifications, or construction has not been started, or soil has been replaced, soil samples will be collected from undisturbed areas within the ROW (Figure 1). Within the undisturbed areas, five to ten subsamples will be collected using a handheld soil probe to a depth of six inches and composited. Once all the subsamples are collected the soil will be thoroughly mixed, and approximately one gallon of material will be placed in a plastic bag and delivered to the laboratory for analysis. These samples will provide an estimate of the topsoil soil chemistry from the project site. The collection of non-disturbed samples will be used to represent the no salvage alternative when top soiling was completed properly. This collection method will allow for the comparison of all salvage alternatives at all sites.

  - **NRCS Salvage Sample-** Soil samples will be obtained at depths suggested by the NRCS soil survey for the project site. The NRCS soil survey will be reviewed to determine appropriate topsoil salvage depths based on soil mapping units. Soil samples will be collected from undisturbed areas within the ROW. Within the undisturbed areas, five to ten subsamples will be collected using a handheld soil probe to a recommended depth and composited. Once all the subsamples are collected the soil sample will be thoroughly mixed, and approximately one gallon of material will be placed in a plastic bag and delivered to the laboratory for analysis. These samples will provide an estimate of the topsoil soil chemistry from the project site. The NRCS soil survey data is intended to increase topsoil salvage depth accuracy while at the same time not having to add additional field time and expense. It is possible that some project sites may not have a completed or available NRCS soil survey. In those situations no soil samples will be obtained for this scenario.

- **Field Verified Salvage Sample-**Soil samples will be collected from depths identified by the soil scientist in the field within undisturbed locations of the ROW at each identified project site. The soil scientist will identify the depth of the topsoil in the field based on morphological features and genetic horizons at 5 locations at each project site. Once the topsoil is identified soil samples will be obtained to the appropriate depth using handheld soil probes or a shovel. Once all the subsamples are collected, the collected soil will be thoroughly mixed and approximately one gallon of material will be placed in a plastic bag and delivered to the laboratory for analysis. These samples will provide an estimate of the actual topsoil soil chemistry from the project site.

Figure 1
Stockpiled Soil Sampling Strategies



# Appendix C

Once the appropriate soil samples are collected, the samples will be delivered to the qualified laboratory for analysis. Soil samples will be analyzed for the parameters as defined in Table 2 below:

Table 2
Analytical Testing Parameters for Soil Samples

| MEASUREMENT | Extraction Method | Analysis Method |
|---|---|---|
| pH, Saturated Paste | ASA Mono. #9, Part 2, Method 10-3.2 | pH Meter |
| Conductivity (EC), saturated paste | ASA Mono. #9, Part 2, Method 10-3.3 | Conductivity Meter |
| Saturation Percentage | USDA Handbook 60, Method 27A | N/A |
| Calcium (Saturated Paste) | ASA Mono. #9, Part 2, Method 10-2.3.1 | E6010B/E6020 |
| Magnesium (Saturated Paste | ASA Mono. #9, Part 2, Method 10-2.3.1 | E6010B/E6020 |
| Sodium (Saturated Paste) | ASA Mono. #9, Part 2, Method 10-2.3.1 | E6010B/E6020 |
| Sodium Adsorption Ratio (SAR) | ASA Mono. #9, Part 2, Method 10-3.4 | E6010B/E6020 |
| Texture Includes % sand, silt, clay | ASA Mono. #9, Part 1, Method 15-4 | Pipette |
| Lime as CaCO3 | USDA Handbook 60, Method 23C | Titration |
| Plant Available Phosphorus | ASA Mono. #9, Part 2, Method 24-5.4 | Colorimeter |
| NH4-N | Methods of Soil Analysis, Part 3. Chemical Methods. Chp 38 Nitrogen–Inorganic Forms | Colorimetric |
| NO3-N | Methods of Soil Analysis, Part 3. Chemical Methods. Chp 38 Nitrogen–Inorganic Forms | Colorimetric |
| Available Potassium | Soil & Plant Analysis Council Method 7.3 | Atomic Absorption |
| Organic Matter | Soil & Plant Analysis Council Method 13.2 | LOI |

In addition to the laboratory analysis, the following field tests will be conducted to assist in the topsoil salvage evaluations:

- Field texture
- Effervescence
- % coarse fragments

It should be noted that surface soils and/or salvage pile samples will be collected at the same CDOT selected projects for the Construction Revegetation Quality Control Task (Table 1).

Data Management and Analysis

The goal of the field testing and laboratory analysis is to identify soils that have chemical characteristics that are not conducive to revegetation success. The analytical testing and field data will be reviewed to calculate recommended soil amendments to promote efficient and successful revegetation. The laboratory and field data will be compiled in an Excel spreadsheet and presented in the final report in tables and figures. The data will be utilized to create cost comparisons for each particular topsoil salvage methodology used by the contactor. Results will also be described and discussed in the final report.

# Appendix C

It should be noted that all soil samples will be collected using standard scientific methodology, and direct comparisons and trends may be identified through the data analysis. However due to a lack of replication and a true experimental design (due to budget constraints), statistical analysis of the results will not be completed. Although statistical analysis will not be completed, the data will be reviewed to identify techniques and approaches that have had better success at multiple locations and those top soiling techniques that CDOT may further explore as funding becomes available.

## 5.0 Forensic Revegetation Analysis

The objective of the forensic revegetation analysis is to determine the revegetation processes and crucial growth variables that had success on historical construction sites. This task will compare the methods used across CDOT regions to determine if consistent revegetation variables impact reclamation success.

### Working Hypothesis

Improved revegetation occurs at construction sites if contractors follow CDOT specifications and contract requirements. Reclamation success between CDOT regions can be attributed to correctly implementing CDOT specifications. Certain critical revegetation variables control reclamation success throughout most CDOT regions.

### Overview of Field Task Approach

Previously revegetated sites will be visited, and data will be collected regarding topsoil characteristics, vegetative cover and composition, site topographic position and orientation, hydrology, and roadway design. This data will be analyzed and interpreted to determine whether or not sites have been revegetated successfully. The team will then compare site conditions and specifications to determine if reclamation success is directly related to certain variables or to following predefined specifications.

### Forensic Field Study Locations

Table 3 contains the locations selected by the study panel technical lead, which will be evaluated by the TerraLogic team. If the study panel determines that different project sites better meet the goals of this project, sites may be substituted so long this does not significantly alter costs, e.g. extended travel times. TerraLogic will periodically communicate with the CDOT study panel leader, Mike Banovich, regarding any site changes.

Table 3
Forensic Analysis Locations

| Project | Location/CDOT Region | Topography |
|---|---|---|
| US-40 Berthoud Pass (Phase I) | Empire/Region 1 | Mountain |
| US-40 Berthoud Pass (Phase II) | Empire/Region 1 | Mountain |
| US-285 (Phase II) | Conifer/Region 1 | Foothill |
| I-25 TREX (Yale and or University) | Denver/Region 1 | Urban |
| North Powers Extension | Colorado Springs/Region 1 | Urban |
| US 85 Titan Road | Region 1 | Rural |

# Appendix C

Site Characteristics

At each project site the TerraLogic team and CDOT representatives will evaluate the general site conditions based on historical data and site conditions including, but not limited to:

- Reclamation history
- Specifications
- Seed mix
- Location
- Production
- Aspect
- Slope
- Topographic position
- Site stability
- Geology
- Hydrological characteristics (drainage, run-on/run-off)
- Ecological habitat continuity
- Roadway design elements

These site parameters will be used to assist in the data interpretations and allow for comparisons between sites.

Vegetative Characteristics

At each individual site, vegetative cover and composition will be assessed using line-point intercept transects placed at five representative locations throughout a revegetated area and five representative locations in the adjacent off-ROW reference area. Sites will be selected during the field data collection visit by the TerraLogic team or by a qualified CDOT field representative.

Line-point intercept methods will follow USDA ARS 2005 with the exception that only vegetation will be assessed. Plants will be identified to species level where possible. Each transect will be 100 feet in length, with data collected every 10 feet starting at the "10 foot " location, and 10 data points collected along each transect. This will result in the collection of data at 50 points in revegetated areas and at 50 points in off-ROW areas for each site. All data will be recorded on standardized field data sheets. CDOT will provide a plant identification specialist to support this work.

Qualitative characteristics of identified dominant vegetative species will also be recorded on data sheets for each previous construction site. This will include notes on phenology (stage of vegetation growth, i.e., rosette, vegetative, flowering, fruiting, dehiscent), evidence of grazing or herbivory, overall health of individuals, native plant abundance and ecological continuity.

Soil Characteristics

Soil will be evaluated in the field using standard field sampling methodology. At the site the topsoil depths will be described to a maximum depth of 12 inches. Key features will be identified including:

- Texture
- Structure
- Effervescence
- Color
- Redoximorphic features (pigment color formed by the oxidation/reduction of Fe and/or Mn)
- Roots

In addition field measurements for pH and EC will be obtained from the topsoil layers. All field measurements will be conducted on a 1:1 (v/v) water to soil ratio. This analysis method will allow for quick and uniform sampling throughout the identified project sites, and allow for comparisons between sites. All data will be recorded on field forms during the site visit. Soils will be evaluated from both the ROW and adjacent off-ROW reference sites positions. If necessary, soil samples will be collected for laboratory testing for parameters identified in Table 2.

### Data Evaluation

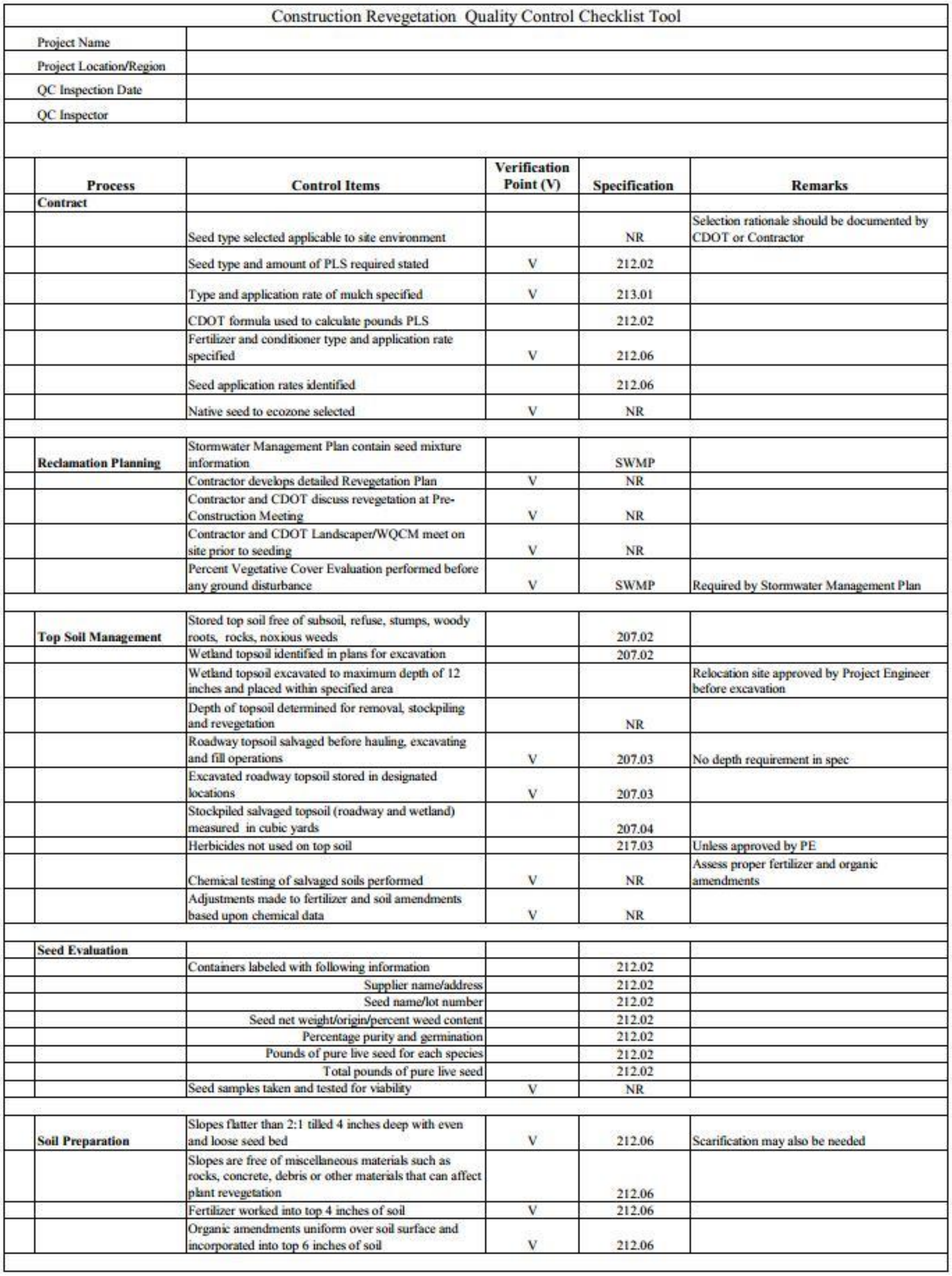
Data will be reviewed based on site specific conditions and field data collected. Review will be conducted based on historical reclamation practices and current vegetative states. The team will not review weather data trends during the reclamation process, but recognizes that such environmental factors are factors in revegetation success or failure, potentially limiting the conclusions drawn from such forensic analysis. Trends in the data will be evaluated through tables and figures. The data evaluation and results will be discussed in the final research report.

## 5.0 Statewide Survey of Resident Engineers

The three main tasks of the study plan (Salvage Soil Management, Construction Revegetation Quality Control, and Forensic Revegetation Analysis) are expected to identify or confirm trends that contribute to slow or ineffective revegetation. Based on those trends, a survey will be sent (via the CDOT study panel) to a group of engineers statewide, likely the CDOT design / construction resident engineers. The goal of the survey is to determine how widespread these trends are in CDOT outside of the selected sites described above, and to allow the TerraLogic team and the study panel the opportunity to make inquiries which may lead to further study outside of the scope of this project.

The TerraLogic team will write the survey questions (no more than 25) and submit them to the study panel for review. Once the survey is finalized, the questions will be sent to resident engineers by CDOT, likely with the aid of a web-based form such as Survey Monkey. CDOT staff will assist with the Survey Monkey process. The results of the survey will be compiled and tabulated in a simple descriptive manner, compared with other results from this research project, and recommendations regarding the results will be made (including the potential for recommendations for further research). Statistical analysis will not be completed due to lack of replication; however, the trends will be thoroughly evaluated and referenced through the data analysis section.

## Appendix C-1

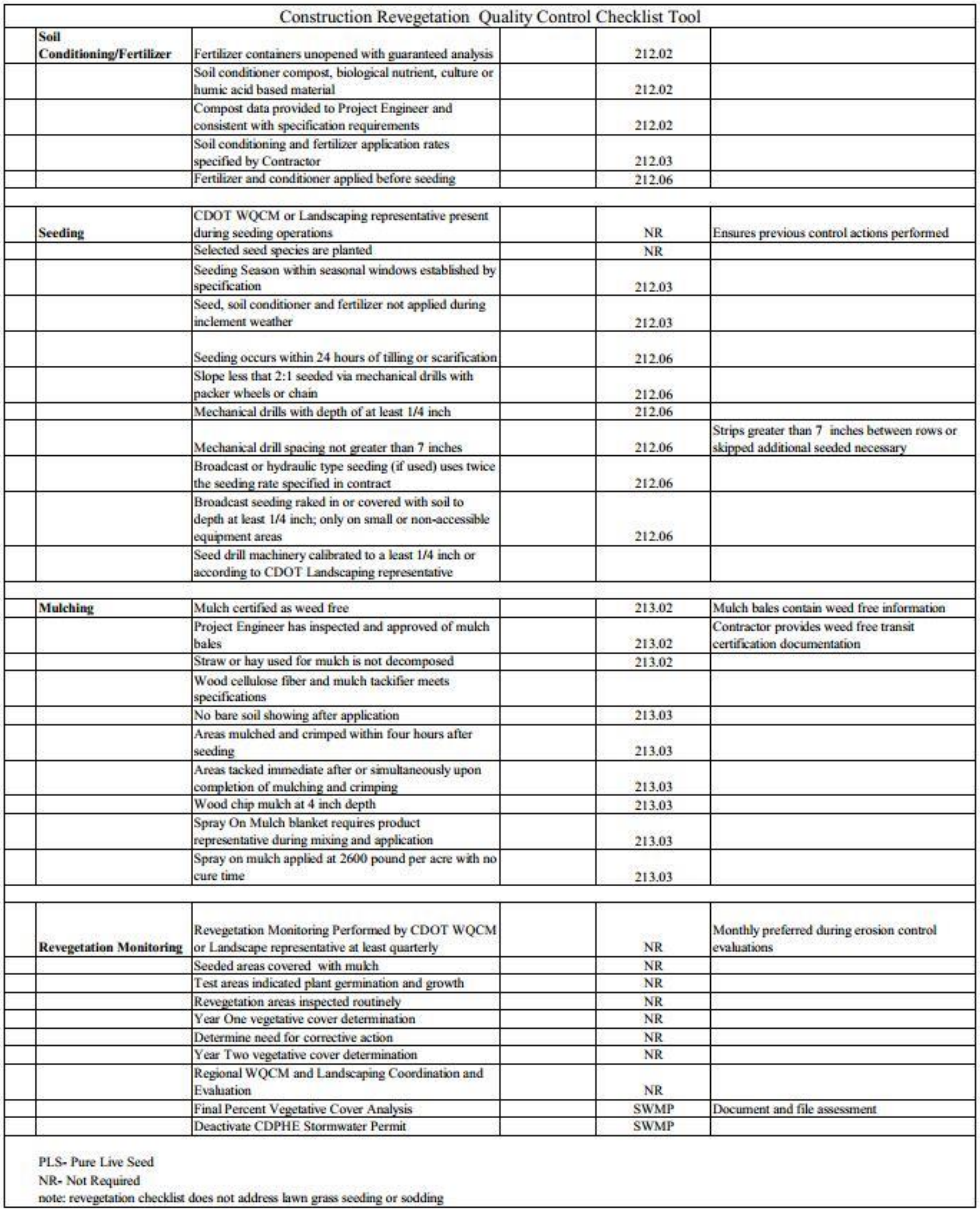


Construction Revegetation Quality Control Checklist Tool

| | |
|---|---|
| Project Name | |
| Project Location/Region | |
| QC Inspection Date | |
| QC Inspector | |

| Process | Control Items | Verification Point (V) | Specification | Remarks |
|---|---|---|---|---|
| **Contract** | | | | |
| | Seed type selected applicable to site environment | | NR | Selection rationale should be documented by CDOT or Contractor |
| | Seed type and amount of PLS required stated | V | 212.02 | |
| | Type and application rate of mulch specified | V | 213.01 | |
| | CDOT formula used to calculate pounds PLS | | 212.02 | |
| | Fertilizer and conditioner type and application rate specified | V | 212.06 | |
| | Seed application rates identified | | 212.06 | |
| | Native seed to ecozone selected | V | NR | |
| | | | | |
| **Reclamation Planning** | Stormwater Management Plan contain seed mixture information | | SWMP | |
| | Contractor develops detailed Revegetation Plan | V | NR | |
| | Contractor and CDOT discuss revegetation at Pre-Construction Meeting | V | NR | |
| | Contractor and CDOT Landscaper/WQCM meet on site prior to seeding | V | NR | |
| | Percent Vegetative Cover Evaluation performed before any ground disturbance | V | SWMP | Required by Stormwater Management Plan |
| | | | | |
| **Top Soil Management** | Stored top soil free of subsoil, refuse, stumps, woody roots, rocks, noxious weeds | | 207.02 | |
| | Wetland topsoil identified in plans for excavation | | 207.02 | |
| | Wetland topsoil excavated to maximum depth of 12 inches and placed within specified area | | | Relocation site approved by Project Engineer before excavation |
| | Depth of topsoil determined for removal, stockpiling and revegetation | | NR | |
| | Roadway topsoil salvaged before hauling, excavating and fill operations | V | 207.03 | No depth requirement in spec |
| | Excavated roadway topsoil stored in designated locations | V | 207.03 | |
| | Stockpiled salvaged topsoil (roadway and wetland) measured in cubic yards | | 207.04 | |
| | Herbicides not used on top soil | | 217.03 | Unless approved by PE |
| | Chemical testing of salvaged soils performed | V | NR | Assess proper fertilizer and organic amendments |
| | Adjustments made to fertilizer and soil amendments based upon chemical data | V | NR | |
| | | | | |
| **Seed Evaluation** | | | | |
| | Containers labeled with following information | | 212.02 | |
| | Supplier name/address | | 212.02 | |
| | Seed name/lot number | | 212.02 | |
| | Seed net weight/origin/percent weed content | | 212.02 | |
| | Percentage purity and germination | | 212.02 | |
| | Pounds of pure live seed for each species | | 212.02 | |
| | Total pounds of pure live seed | | 212.02 | |
| | Seed samples taken and tested for viability | V | NR | |
| | | | | |
| **Soil Preparation** | Slopes flatter than 2:1 tilled 4 inches deep with even and loose seed bed | V | 212.06 | Scarification may also be needed |
| | Slopes are free of miscellaneous materials such as rocks, concrete, debris or other materials that can affect plant revegetation | | 212.06 | |
| | Fertilizer worked into top 4 inches of soil | V | 212.06 | |
| | Organic amendments uniform over soil surface and incorporated into top 6 inches of soil | V | 212.06 | |

# Appendix C-1



Construction Revegetation Quality Control Checklist Tool

| | | | | |
|---|---|---|---|---|
| **Soil Conditioning/Fertilizer** | Fertilizer containers unopened with guaranteed analysis | | 212.02 | |
| | Soil conditioner compost, biological nutrient, culture or humic acid based material | | 212.02 | |
| | Compost data provided to Project Engineer and consistent with specification requirements | | 212.02 | |
| | Soil conditioning and fertilizer application rates specified by Contractor | | 212.03 | |
| | Fertilizer and conditioner applied before seeding | | 212.06 | |
| | | | | |
| **Seeding** | CDOT WQCM or Landscaping representative present during seeding operations | | NR | Ensures previous control actions performed |
| | Selected seed species are planted | | NR | |
| | Seeding Season within seasonal windows established by specification | | 212.03 | |
| | Seed, soil conditioner and fertilizer not applied during inclement weather | | 212.03 | |
| | Seeding occurs within 24 hours of tilling or scarification | | 212.06 | |
| | Slope less that 2:1 seeded via mechanical drills with packer wheels or chain | | 212.06 | |
| | Mechanical drills with depth of at least 1/4 inch | | 212.06 | |
| | Mechanical drill spacing not greater than 7 inches | | 212.06 | Strips greater than 7 inches between rows or skipped additional seeded necessary |
| | Broadcast or hydraulic type seeding (if used) uses twice the seeding rate specified in contract | | 212.06 | |
| | Broadcast seeding raked in or covered with soil to depth at least 1/4 inch; only on small or non-accessible equipment areas | | 212.06 | |
| | Seed drill machinery calibrated to a least 1/4 inch or according to CDOT Landscaping representative | | | |
| | | | | |
| **Mulching** | Mulch certified as weed free | | 213.02 | Mulch bales contain weed free information |
| | Project Engineer has inspected and approved of mulch bales | | 213.02 | Contractor provides weed free transit certification documentation |
| | Straw or hay used for mulch is not decomposed | | 213.02 | |
| | Wood cellulose fiber and mulch tackifier meets specifications | | | |
| | No bare soil showing after application | | 213.03 | |
| | Areas mulched and crimped within four hours after seeding | | 213.03 | |
| | Areas tacked immediate after or simultaneously upon completion of mulching and crimping | | 213.03 | |
| | Wood chip mulch at 4 inch depth | | 213.03 | |
| | Spray On Mulch blanket requires product representative during mixing and application | | 213.03 | |
| | Spray on mulch applied at 2600 pound per acre with no cure time | | 213.03 | |
| | | | | |
| **Revegetation Monitoring** | Revegetation Monitoring Performed by CDOT WQCM or Landscape representative at least quarterly | | NR | Monthly preferred during erosion control evaluations |
| | Seeded areas covered with mulch | | NR | |
| | Test areas indicated plant germination and growth | | NR | |
| | Revegetation areas inspected routinely | | NR | |
| | Year One vegetative cover determination | | NR | |
| | Determine need for corrective action | | NR | |
| | Year Two vegetative cover determination | | NR | |
| | Regional WQCM and Landscaping Coordination and Evaluation | | NR | |
| | Final Percent Vegetative Cover Analysis | | SWMP | Document and file assessment |
| | Deactivate CDPHE Stormwater Permit | | SWMP | |

PLS- Pure Live Seed

NR- Not Required

note: revegetation checklist does not address lawn grass seeding or sodding

# Appendix D: Field Visit Observation Summary Reports (D-1 through D-5)

Available on Final Report Appendices CD.

# Appendix E: Construction Revegetation QC Database (E-1 through E-5)

Available on Final Report Appendices CD.

# Appendix F: Pages extracted from “Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems, Volume I: Quick Start

# Monitoring Manual

## for Grassland, Shrubland and Savanna Ecosystems

### Volume I: Quick Start

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# Line-point intercept

Line-point intercept is a rapid, accurate method for quantifying soil cover, including vegetation, litter, rocks and biotic crusts. These measurements are related to wind and water erosion, water infiltration and the ability of the site to resist and recover from degradation. For a detailed discussion of this and other methods for measuring plant cover and/or composition, see Elzinga et al. 2001[2]. For alternative Line-point intercept methods (including height measurements) see Volume II.

## Materials

- **Measuring tape (length of transect)—if using a tape measure in feet, use one marked in tenths of feet.**
- **Two steel pins for anchoring tape**
- **One pointer—a straight piece of wire or rod, such as a long pin flag, at least 75 cm (2.5 ft) long and less than 1 mm (1/25 in) in diameter**
- **Clipboard, Line-Point Intercept Data Form (page 12) and pencil(s)**

## Standard methods (rule set)

**1. Pull out the tape and anchor each end with a steel pin (Fig. 6).**

***Rules***

1.1 Line should be taut.

1.2 Line should be as close to the ground as possible (thread under shrubs using a steel pin as a needle).

**2. Begin at the "0" end of the line.**

**3. Working from left to right, move to the first point on the line. Always stand on the same side of the line.**

**Figure 6.** Transect line pulled taut.

**4. Drop a pin flag to the ground from a standard height (__ cm (__in)) next to the tape (Fig. 7).**

***Rules***

4.1 The pin should be vertical.

4.2 The pin should be dropped from the same height each time. A low drop height minimizes "bounces" off of vegetation but increases the possibility for bias.

4.3 Do not guide the pin all the way to the ground. It is more important for the pin to fall freely to the ground than to fall precisely on the mark.

**Step-point or pace transect with pin (Semiquantitative alternative)**

**Use a pin flag dropped in front of your boot instead of the points on the tape.**

**Limitations:**
Less accurate because it is difficult to walk a straight line, especially through shrubs. Using the toe of a boot instead of a pin creates additional errors because the boot often pushes plant canopies into interspaces. This leads to overestimates of plant canopy cover.

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[2] Elzinga, C.L., D.W. Salzer, J.W. Willoughby and J.P. Gibbs. 2001. *Monitoring Plant and Animal Populations*, Blackwell Publishing. 368 pp.

4.4 A pair of lasers with a bubble level can be used instead of the pin. This tool is useful in savannas where canopy layers may be above eye level. See Appendix A (Monitoring tools) in Volume II for suppliers.

**5. Once the pin flag is flush with the ground, record every plant species it intercepts.**

***Rules***

5.1 Record the species of the first stem, leaf or plant base intercepted in the "Top canopy" column using the PLANTS database species code (http://plants.usda.gov/), a four-letter code based on the first two letters of the genus and species, or the common name.

5.2 If no leaf, stem or plant base is intercepted, record "NONE" in the "Top canopy" column.

5.3 Record all additional species intercepted by the pin.

5.4 Record herbaceous litter as "L," if present. Litter is defined as detached dead stems and leaves that are part of a layer that comes in contact with the ground. Record "W" for detached woody litter that is greater than 5 mm (or ~1/4 in) in diameter and in direct contact with soil.

5.5 Record each canopy species only once, even if it is intercepted several times.

5.6 If you can identify the genus, but not the species either use the PLANTS database genus code (http://plants.usda.gov) or record a number for each new species of that genus. ALWAYS define the genus portion of the code and the functional group at the bottom of the data form (*Artemisia* species = AR01).

5.7 If you *cannot* identify the genus, use the following codes:

**AF#** = Annual forb (also includes biennials)
**PF#** = Perennial forb
**AG#** = Annual graminoid
**PG#** = Perennial graminoid
**SH#** = Shrub
**TR#** = Tree

If necessary, collect a sample of the unknown off the transect for later identification.

**Figure 7.** Point falling on bare soil (NONE/S).

5.8 Canopy can be live or dead, but only record each species once. Be sure to record all species intercepted.

**6. Record whether the pin flag intercepts a plant base (Fig. 8) or one of the following in the "Soil surface" column.**

**R** = Rock (> 5 mm or ~1/4 inch in diameter)
**BR** = Bedrock
**EL** = Embedded litter
**D** = Duff
**M** = Moss
**LC** = Lichen crust on soil (lichen on rock is recorded as "R")
**S** = Soil that is visibly unprotected by any of the above

***Rules***

6.1 For unidentified plant bases, use the codes listed under 5.7.

6.2 Record embedded litter as "EL" where removal of the litter would leave an indentation in the soil surface or would disturb the soil surface. Record duff as "D" where there is no clear boundary between litter and soil and litter is not removed during typical storms (occurring annually).

6.3 Additional categories may be added, such as "CYN" = dark cyanobacterial crust.

**Table 2.** Sample data form for examples illustrated below. Points 1 and 2 show the first two points on a line. In Point 1, the pin flag is touching dead fescue, live bluegrass, clover, live fescue, litter and a rock. Record fescue only once, even though it intercepts the pin twice. In Point 2, the flag touches fescue, then touches litter and finally the fescue plant base. Table 2 shows how to record these two points on the data form.

| Pt. | Top canopy | Lower canopy layers | | | Soil surface |
|---|---|---|---|---|---|
| | | Code 1 | Code 2 | Code 3 | |
| 1 | Fescue | Bluegrass | Clover | L | R |
| 2 | Fescue | L | | | Fescue |
| 3 | Fescue | L | | | S |
| etc. | | | | | |

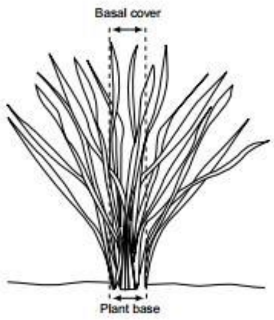
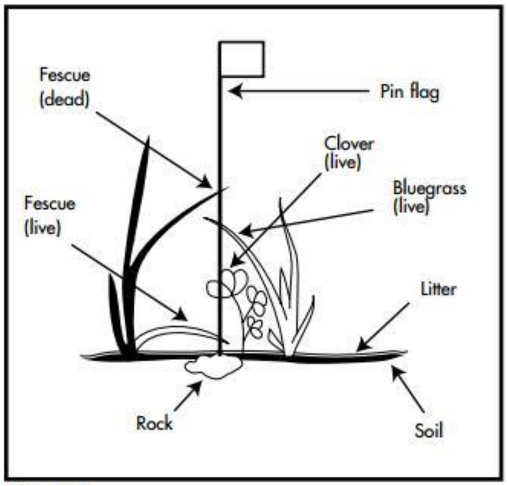
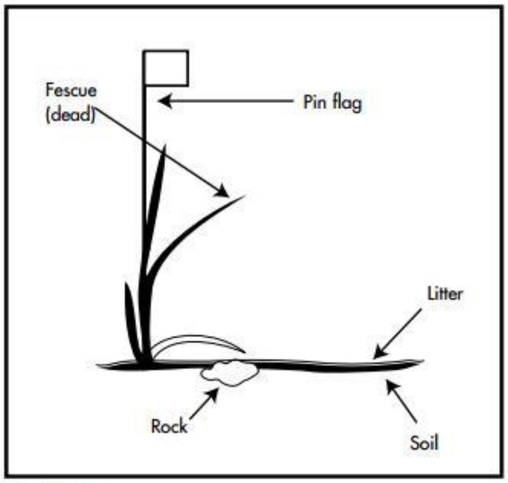


**Figure 8.** Area defined as plant base and included as basal cover.

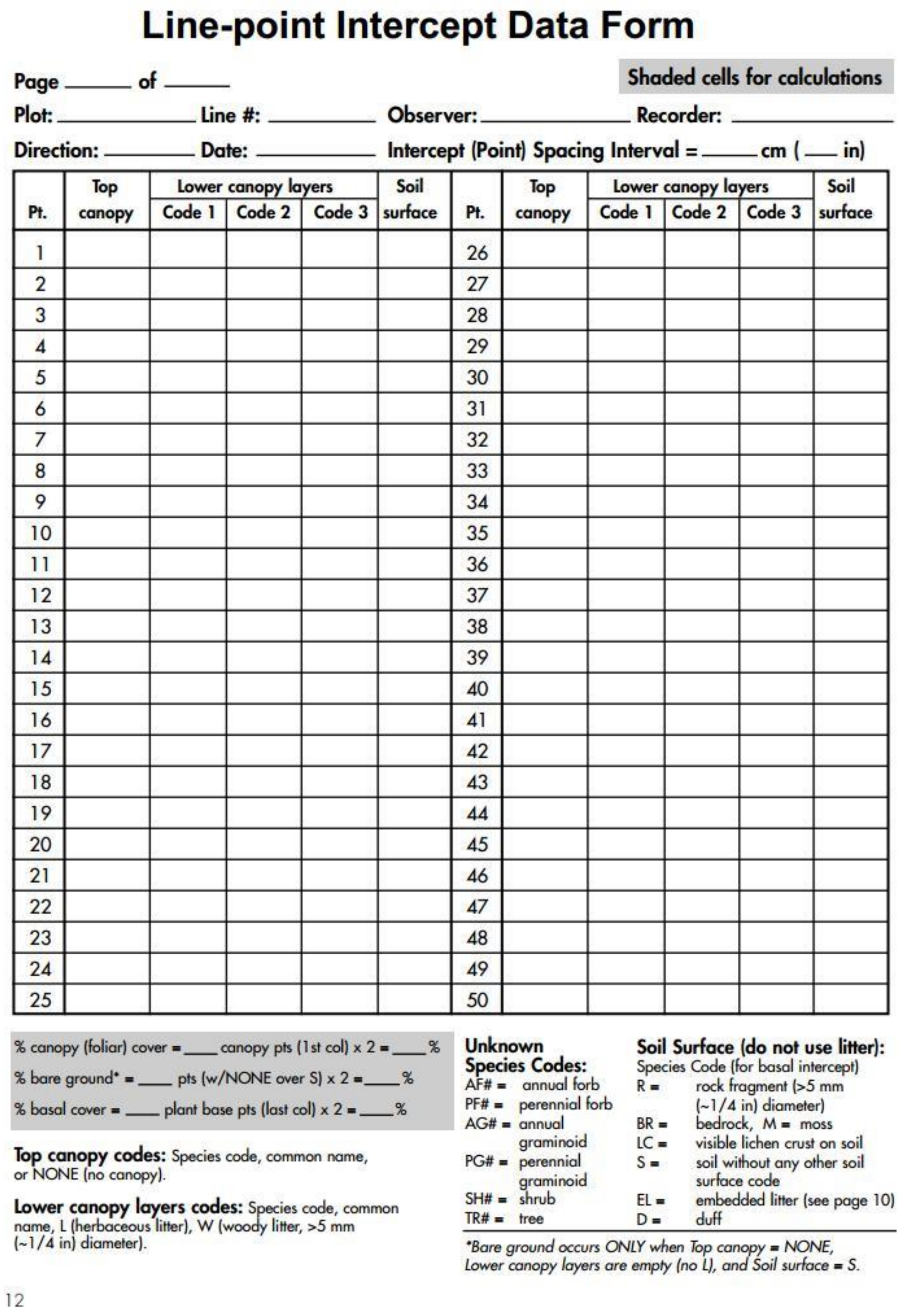


**Point 1**



**Point 2**

**Riparian note:** Line-point intercept collected perpendicular to the channel is often used to monitor riparian zone width. A modified point intercept method is used to monitor "greenline" vegetation along the channel's edge (Vol. II, Chapter 13).



# Line-point Intercept Data Form

**Page _____ of _____**

**Shaded cells for calculations**

**Plot: __________ Line #: ________ Observer: __________ Recorder: __________**

**Direction: _______ Date: ________ Intercept (Point) Spacing Interval = _____ cm ( ___ in)**

| | **Top** | **Lower canopy layers** | | | **Soil** | | **Top** | **Lower canopy layers** | | | **Soil** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pt.** | **canopy** | **Code 1** | **Code 2** | **Code 3** | **surface** | **Pt.** | **canopy** | **Code 1** | **Code 2** | **Code 3** | **surface** |
| 1 | | | | | | 26 | | | | | |
| 2 | | | | | | 27 | | | | | |
| 3 | | | | | | 28 | | | | | |
| 4 | | | | | | 29 | | | | | |
| 5 | | | | | | 30 | | | | | |
| 6 | | | | | | 31 | | | | | |
| 7 | | | | | | 32 | | | | | |
| 8 | | | | | | 33 | | | | | |
| 9 | | | | | | 34 | | | | | |
| 10 | | | | | | 35 | | | | | |
| 11 | | | | | | 36 | | | | | |
| 12 | | | | | | 37 | | | | | |
| 13 | | | | | | 38 | | | | | |
| 14 | | | | | | 39 | | | | | |
| 15 | | | | | | 40 | | | | | |
| 16 | | | | | | 41 | | | | | |
| 17 | | | | | | 42 | | | | | |
| 18 | | | | | | 43 | | | | | |
| 19 | | | | | | 44 | | | | | |
| 20 | | | | | | 45 | | | | | |
| 21 | | | | | | 46 | | | | | |
| 22 | | | | | | 47 | | | | | |
| 23 | | | | | | 48 | | | | | |
| 24 | | | | | | 49 | | | | | |
| 25 | | | | | | 50 | | | | | |

% canopy (foliar) cover = ____ canopy pts (1st col) x 2 = ____%

% bare ground* = ____ pts (w/NONE over S) x 2 = ____%

% basal cover = ____ plant base pts (last col) x 2 = ____%

**Top canopy codes:** Species code, common name, or NONE (no canopy).

**Lower canopy layers codes:** Species code, common name, L (herbaceous litter), W (woody litter, >5 mm (~1/4 in) diameter).

**Unknown Species Codes:**

AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

**Soil Surface (do not use litter):**

Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

# Line-point intercept indicator calculations

Canopy cover (as calculated here) does not include bare spaces within a plant's canopy.

**1. Percent canopy (foliar) cover**

***Rules***

1.1 Count the total number of canopy intercepts in the "Top canopy" column and record this number in the blank provided.

1.2 Canopy intercepts include all points where a plant is recorded in the "Top canopy" column. Do not include points that have a "NONE" in the "Top canopy" column.

1.3 Multiply the number of canopy intercepts (from 1.1) by 2* and record your "% canopy cover" in the blank provided.

**2. Percent bare ground**

***Rules***

2.1 Count the total number of points along the line that have bare ground and record this number in the blank provided.

2.2 Bare ground occurs **only** when:
   - A. There are no canopy intercepts (NONE is recorded in the "Top canopy" column).
   - B. There are no litter intercepts ("Lower canopy layers" columns are empty).
   - C. The pin only intercepts bare soil ("S" recorded in the "Soil surface" column).

2.3 Multiply the number of bare ground hits (from 2.1) by 2* and record your "% bare ground" in the blank provided.

**3. Percent basal cover**

***Rules***

3.1 Count the total number of plant basal intercepts in the "Soil surface" column and record this number in the blank provided.

3.2 Plant basal intercepts occur anytime the pin intercepts a live or dead plant base (Species code recorded in "Soil surface" column).

3.3 Multiply the number of basal intercepts (from 3.1) by 2* and record your "% basal cover" in the blank provided.

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*For 50 points per line. Multiply by 1 for 100 points per line. Multiply by 4 for 25 points per line.

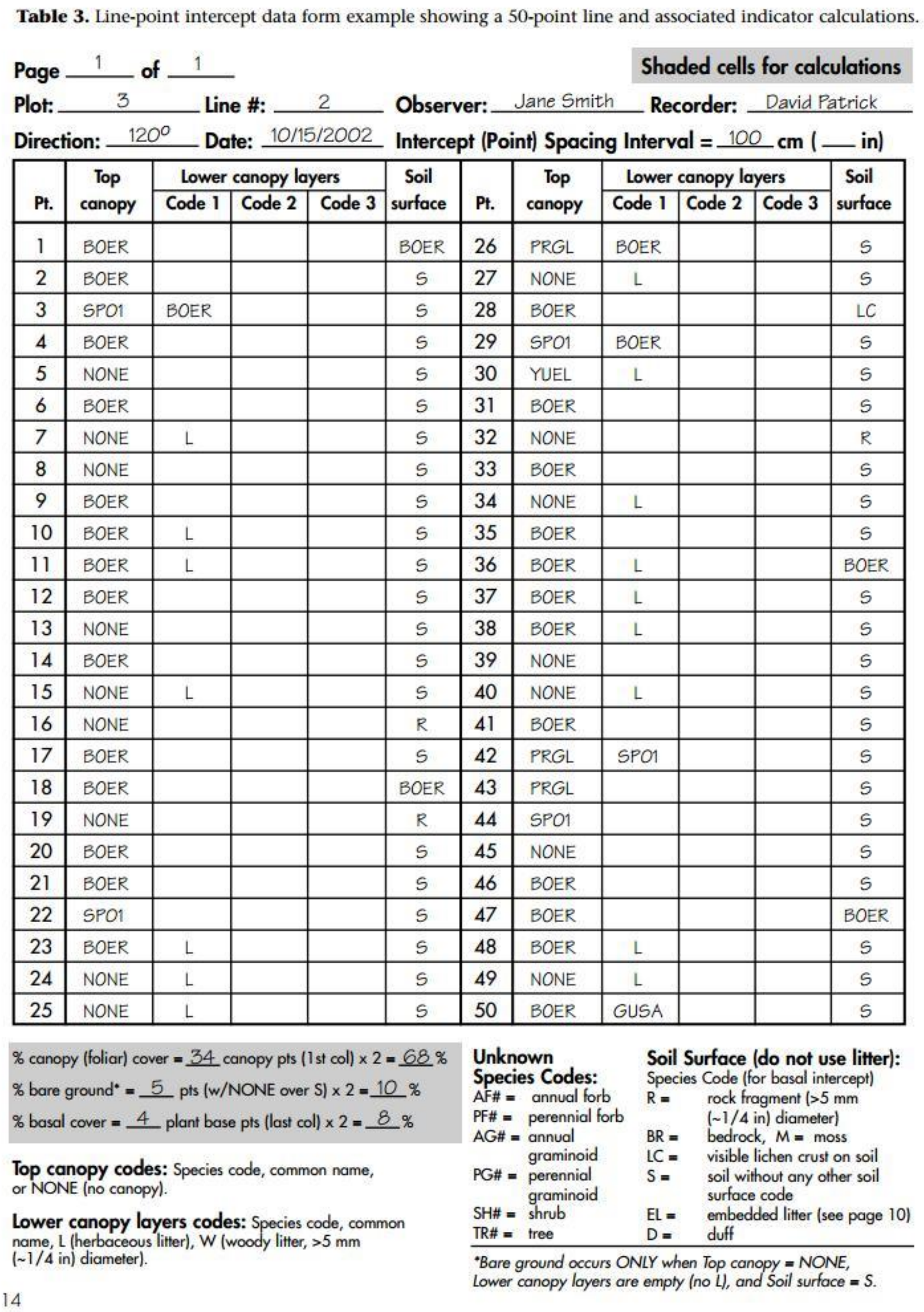

**Table 3.** Line-point intercept data form example showing a 50-point line and associated indicator calculations.

**Page** 1 **of** 1

**Shaded cells for calculations**

**Plot:** 3 **Line #:** 2 **Observer:** Jane Smith **Recorder:** David Patrick

**Direction:** 120° **Date:** 10/15/2002 **Intercept (Point) Spacing Interval =** 100 **cm (** ___ **in)**

| Pt. | Top canopy | Lower canopy layers | | | Soil surface | Pt. | Top canopy | Lower canopy layers | | | Soil surface |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Code 1 | Code 2 | Code 3 | | | | Code 1 | Code 2 | Code 3 | |
| 1 | BOER | | | | BOER | 26 | PRGL | BOER | | | S |
| 2 | BOER | | | | S | 27 | NONE | L | | | S |
| 3 | SP01 | BOER | | | S | 28 | BOER | | | | LC |
| 4 | BOER | | | | S | 29 | SP01 | BOER | | | S |
| 5 | NONE | | | | S | 30 | YUEL | L | | | S |
| 6 | BOER | | | | S | 31 | BOER | | | | S |
| 7 | NONE | L | | | S | 32 | NONE | | | | R |
| 8 | NONE | | | | S | 33 | BOER | | | | S |
| 9 | BOER | | | | S | 34 | NONE | L | | | S |
| 10 | BOER | L | | | S | 35 | BOER | | | | S |
| 11 | BOER | L | | | S | 36 | BOER | L | | | BOER |
| 12 | BOER | | | | S | 37 | BOER | L | | | S |
| 13 | NONE | | | | S | 38 | BOER | L | | | S |
| 14 | BOER | | | | S | 39 | NONE | | | | S |
| 15 | NONE | L | | | S | 40 | NONE | L | | | S |
| 16 | NONE | | | | R | 41 | BOER | | | | S |
| 17 | BOER | | | | S | 42 | PRGL | SP01 | | | S |
| 18 | BOER | | | | BOER | 43 | PRGL | | | | S |
| 19 | NONE | | | | R | 44 | SP01 | | | | S |
| 20 | BOER | | | | S | 45 | NONE | | | | S |
| 21 | BOER | | | | S | 46 | BOER | | | | S |
| 22 | SP01 | | | | S | 47 | BOER | | | | BOER |
| 23 | BOER | L | | | S | 48 | BOER | L | | | S |
| 24 | NONE | L | | | S | 49 | NONE | L | | | S |
| 25 | NONE | L | | | S | 50 | BOER | GUSA | | | S |

% canopy (foliar) cover = 34 canopy pts (1st col) x 2 = 68 %

% bare ground* = 5 pts (w/NONE over S) x 2 = 10 %

% basal cover = 4 plant base pts (last col) x 2 = 8 %

**Top canopy codes:** Species code, common name, or NONE (no canopy).

**Lower canopy layers codes:** Species code, common name, L (herbaceous litter), W (woody litter, >5 mm (~1/4 in) diameter).

**Unknown Species Codes:**

AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

**Soil Surface (do not use litter):**

Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

# Line-point intercept basic interpretation

Increases in **canopy cover** are correlated with increased resistance to degradation. **Basal cover** is a more reliable long-term indicator. Basal cover is less sensitive to seasonal and annual differences in precipitation and use. Increases in **bare ground** nearly always indicate a higher risk of runoff and erosion.

Where species composition changes may be occurring, calculate basal and canopy cover for each major species. Canopy cover usually is used for shrubs, trees and sometimes grasses. Basal cover is used for perennial grasses. When calculating single species canopy cover, be sure to include each time the species is intercepted, regardless of whether it is in the top or lower canopy layer.

Use these indicators together with the indicators from the **Gap intercept** and the **Soil stability test** to help determine whether observed erosion changes are due to loss of cover, changes in the vegetation's spatial distribution, or reduced soil stability. Use these indicators together with the **Belt transect** to track changes in species composition. For more information about how to interpret these indicators, please see Chapter 17 in Volume II.

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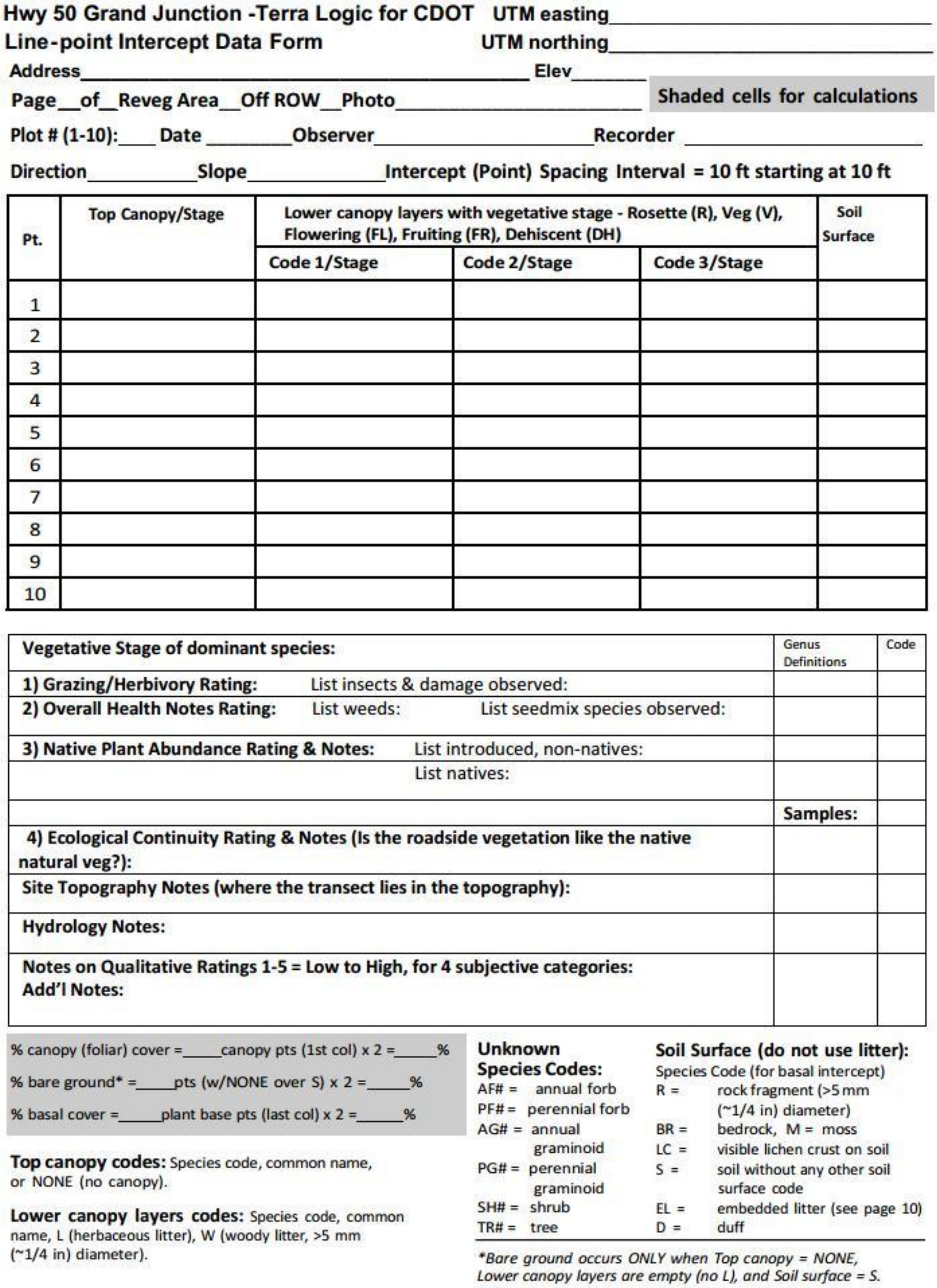
**Typical effect on each attribute of an increase in the indicator value**

| Indicator | Soil and site stability | Hydrologic function | Biotic integrity |
|---|---|---|---|
| Canopy cover (%) | + | + | + |
| Bare ground (%) | – | – | – |
| Basal cover (%) | + | + | + |



**Hwy 50 Grand Junction -Terra Logic for CDOT** **UTM easting**____________________________

**Line-point Intercept Data Form** **UTM northing**____________________________

**Address**__________________________________________ **Elev**________

**Page__of__Reveg Area__Off ROW__Photo**________________________ **Shaded cells for calculations**

**Plot # (1-10):____ Date ________Observer**______________________**Recorder** ________________________

**Direction**____________**Slope**______________**Intercept (Point) Spacing Interval = 10 ft starting at 10 ft**

| Pt. | Top Canopy/Stage | Lower canopy layers with vegetative stage - Rosette (R), Veg (V), Flowering (FL), Fruiting (FR), Dehiscent (DH) | | | Soil Surface |
|---|---|---|---|---|---|
| | | Code 1/Stage | Code 2/Stage | Code 3/Stage | |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |

| | | |
|---|---|---|
| **Vegetative Stage of dominant species:** | Genus Definitions | Code |
| **1) Grazing/Herbivory Rating:** List insects & damage observed: | | |
| **2) Overall Health Notes Rating:** List weeds: List seedmix species observed: | | |
| **3) Native Plant Abundance Rating & Notes:** List introduced, non-natives: | | |
| List natives: | | |
| | **Samples:** | |
| **4) Ecological Continuity Rating & Notes (Is the roadside vegetation like the native natural veg?):** | | |
| **Site Topography Notes (where the transect lies in the topography):** | | |
| **Hydrology Notes:** | | |
| **Notes on Qualitative Ratings 1-5 = Low to High, for 4 subjective categories:**<br>**Add'l Notes:** | | |

% canopy (foliar) cover =_____canopy pts (1st col) x 2 =_____%

% bare ground* =_____pts (w/NONE over S) x 2 =_____%

% basal cover =______plant base pts (last col) x 2 =______%

**Top canopy codes:** Species code, common name, or NONE (no canopy).

**Lower canopy layers codes:** Species code, common name, L (herbaceous litter), W (woody litter, >5 mm (~1/4 in) diameter).

**Unknown Species Codes:**

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SH# = shrub

TR# = tree

**Soil Surface (do not use litter):**

Species Code (for basal intercept)

R = rock fragment (>5 mm (~1/4 in) diameter)

BR = bedrock, M = moss

LC = visible lichen crust on soil

S = soil without any other soil surface code

EL = embedded litter (see page 10)

D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

# Appendix G: Forensic Field Study Database (G-1 through G-5)

Available on Final Report Appendices CD.

# Appendix H: Revegetation Survey of CDOT Construction Project Engineers-Results

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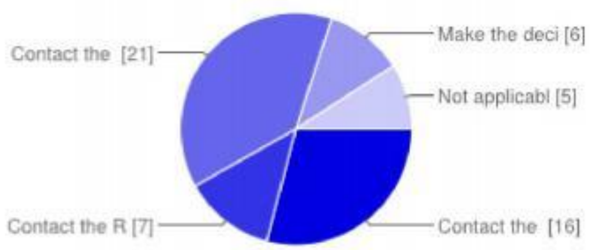
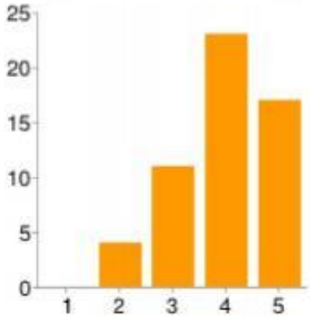
# Summary

## 1. When the prime contractor presents a proposed change in the revegetation specification or a revegetation contract requirement, what action do you usually take?



| | | |
|---|---|---|
| Contact the Regional or EPB Landscape Architect | **16** | 29% |
| Contact the Regional Water Pollution Control Manager | **7** | 13% |
| Contact the Regional Environmental Manager (RPEM) | **21** | 38% |
| Make the decision on your own | **6** | 11% |
| Not applicable | **5** | 9% |

## 2. How would you rate the importance and priority of reviewing and inspecting the subcontractor performance during soil preparation and seeding?



| | | |
|---|---|---|
| 1 | **0** | 0% |
| 2 | **4** | 7% |
| 3 | **11** | 20% |
| 4 | **23** | 42% |
| 5 | **17** | 31% |

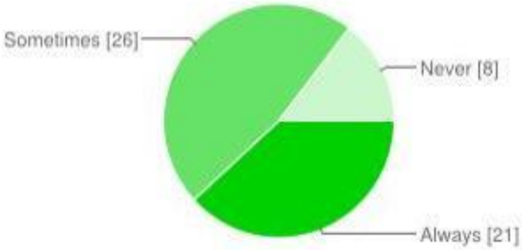
## 3. What level of importance is placed on having a CDOT Landscape Architect or environmental specialist review and approve proposed changes in CDOT seed mixtures

| | | |
|---|---|---|
| 1 | **0** | 0% |
| 2 | **3** | 5% |
| 3 | **12** | 22% |
| 4 | **18** | 33% |
| 5 | **22** | 40% |

## 4. How do you confirm the implementation of soil preparation and seeding according to CDOT specifications on your projects?

| | | |
|---|---|---|
| At the precon | **10** | 18% |
| During weekly meetings | **17** | 31% |
| In the field prior to soil prep and seeding | **45** | 82% |
| Never | **0** | 0% |
| Not applicable to position requirements | **3** | 5% |

## 5. Do you review design plans (SWMP soil prep and seeding) prior to FOR meeting or AD date for projects you are assigned to build or manage?

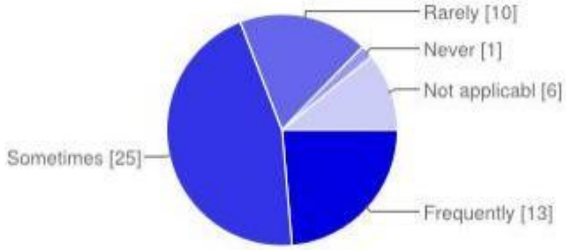


| | | |
|---|---|---|
| Always | **21** | 38% |
| Sometimes | **26** | 47% |
| Never | **8** | 15% |

## 6. Whose responsibility is it to monitor and verify that the project revegetation is progressing as expected from the contractor in preparation for CDOT Maintenance to take over the stormwater permit?

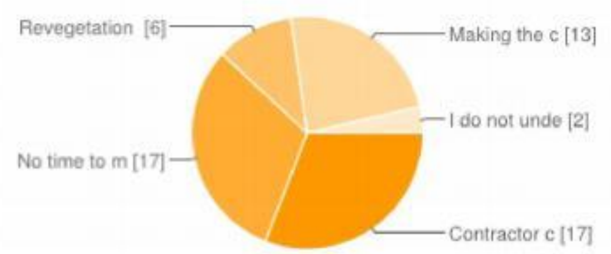
| | | |
|---|---|---|
| Project Engineer | **47** | 85% |
| Regional Landscape Architect | **10** | 18% |
| Regional Water Quality Pollution Manager | **22** | 40% |
| Maintenance representative | **17** | 31% |
| Transportation Erosion Control Supervisor | **21** | 38% |
| Consultant | **5** | 9% |
| Do not know | **3** | 5% |

## 7. How often do you contact the prime contractor about poor revegetation performance during construction and required site re-work?



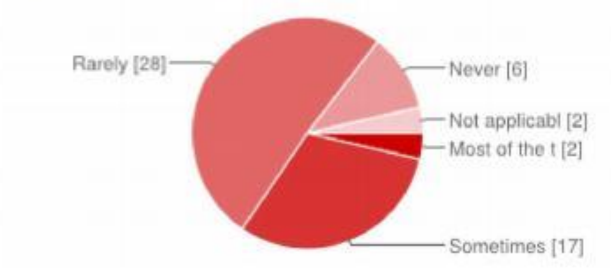
| | | |
|---|---|---|
| Frequently | **13** | 24% |
| Sometimes | **25** | 45% |
| Rarely | **10** | 18% |
| Never | **1** | 2% |
| Not applicable | **6** | 11% |

## 8. What is your biggest challenge in project revegetation?



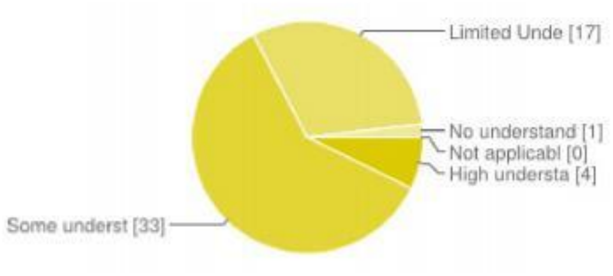
| | | |
|---|---|---|
| Contractor compliance to CDOT specifications | **17** | 31% |
| No time to monitor revegetation performance | **17** | 31% |
| Revegetation gets in the way of project construction | **6** | 11% |
| Making the contractor responsible for revegetation success | **13** | 24% |
| I do not understand revegetation methods | **2** | 4% |

## 9. How often do contractors request revegetation changes to the project requirements?



| | | |
|---|---|---|
| Most of the time | **2** | 4% |
| Sometimes | **17** | 31% |
| Rarely | **28** | 51% |
| Never | **6** | 11% |
| Not applicable | **2** | 4% |

## 10. What level of understanding do you feel that contractors have of CDOT revegetation specifications?

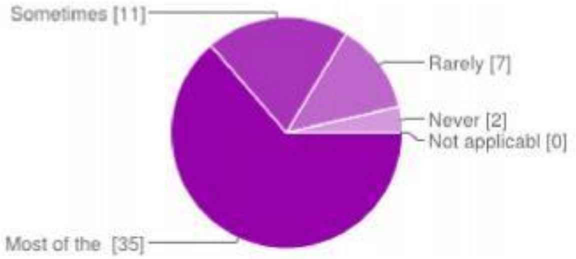


| | | |
|---|---|---|
| High understanding | **4** | 7% |
| Some understanding | **33** | 60% |
| Limited Understanding | **17** | 31% |
| No understanding | **1** | 2% |
| Not applicable | **0** | 0% |

## 11. Seeding outside of CDOT specified seeding windows has a negative effect on revegetation success? How can CDOT improve the scheduling process?

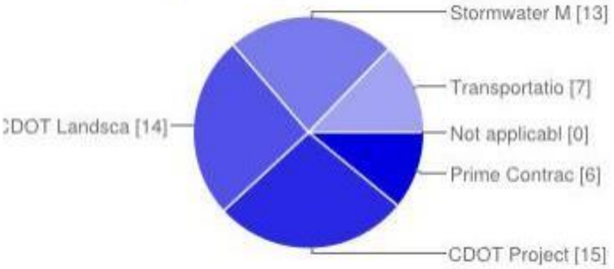
| | | |
|---|---|---|
| Never allow seeding outside window | **13** | 24% |
| Defer seeding to later date beyond project scheduled completion | **22** | 40% |
| Temporarily stabilize and accept the project. Then conduct soil prep and seed projects within separate revegetation contract | **28** | 51% |
| Other | **16** | 29% |

## 12. Are the contractor revegetation requirements and expectations discussed early in the project during the Environmental Pre-Construction Meeting?



| | | |
|---|---|---|
| Most of the time | **35** | 64% |
| Sometimes | **11** | 20% |
| Rarely | **7** | 13% |
| Never | **2** | 4% |
| Not applicable | **0** | 0% |

## 13. Who is usually responsible for conducting the pre-construction vegetation cover analysis for the stormwater permit?

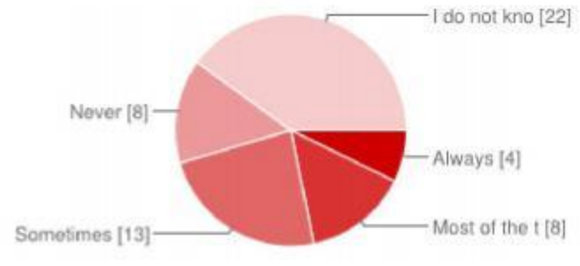


| | | |
|---|---|---|
| Prime Contractor/Landscaping Subcontractor | **6** | 11% |
| CDOT Project Engineer | **15** | 27% |
| CDOT Landscape Architect | **14** | 25% |
| Stormwater Management Plan Designer | **13** | 24% |
| Transportation Erosion Control Supervisor | **7** | 13% |
| Not applicable | **0** | 0% |

## 14. Who is responsible for conducting the post-construction vegetation cover analysis for the stormwater permit?

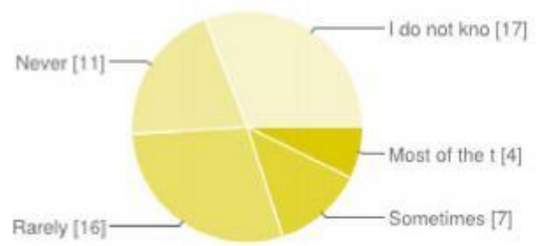
| | | |
|---|---|---|
| Prime Contractor/Erosion Control/Seeding Subcontractor | **17** | 31% |
| CDOT Project Engineer | **24** | 44% |
| CDOT Landscape Architect | **16** | 29% |
| CDOT Regional Water Pollution Control Manager | **28** | 51% |
| Unknown | **4** | 7% |

## 15. Do projects coordinate with CDOT maintenance to avoid herbicide spraying in ROW areas undergoing revegetation?



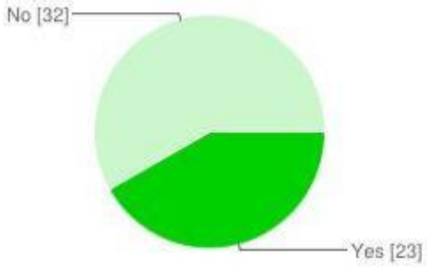
| | | |
|---|---|---|
| Always | **4** | 7% |
| Most of the time | **8** | 15% |
| Sometimes | **13** | 24% |
| Never | **8** | 15% |
| I do not know | **22** | 40% |

## 16. How often has a CDOT Maintenance representative refused to sign off on a punch list that transfers stormwater permit responsibilities to them?



| | | |
|---|---|---|
| Most of the time | **4** | 7% |
| Sometimes | **7** | 13% |
| Rarely | **16** | 29% |
| Never | **11** | 20% |
| I do not know | **17** | 31% |

## 17. Do you think a more detailed revegetation plan in the Stormwater Management Plan would be helpful in terms of project execution?



| | | |
|---|---|---|
| Yes | **23** | 42% |
| No | **32** | 58% |

## 18. At what point in design or construction are most revegetation changes requested?

Towards the end of construction when trying to get final acceptance.

1 month prior to seeding

Day of revegetation :) Contractors see this as a low cost and low risk activity, so they do little planning and only encounter issues just before or during. reveg.

FIR

Usually a few weeks before seeding takes place.

Near the end of the construction on project.

.

Changes are typically requested during construction if/when the seed supplier is unable to make the designated seed mixture.

Prior to ad

Before the contractor goes to work.

NA

Just prior to seeding

Usually they are requested a few weeks prior to installation. Some times the request is due to unavailable supply or the Contractor has a better/ substitute product he would like to use.

In construction changes are usually requested shortly before the contractor or sub-contractor wish to perform the work.

When needed

Do not know

1-2 weeks prior to starting the work.

Early

Construction

I don't really know. We really don't get completed SWMP plans until right before ad. There is usually a cookie cutter SWMP in all FIR and FOR plan sets that I've reviewed in the past. So there really isn't enough time to request any changes.

I don't have enough experience to properly respond to this question.

Most of the time the contractor is looking to change from the more high labor tasks such as EC blankets to spray on mulch blankets. We do not allow this unless the Contractor can prove there is a solid reason to make any changes to the existing plans. We look at this on an individual basis usually towards the end of the project.

Whenever the contractor/subcontractor is ready to order materials is when changes seem to come.

I have had no experience with a revegetation change.

During construction when scheduling or changes in the contract have changed completion dates and planned landscape work can't happen during the appropriate season.

at the end of construction

Prior to seeding operations.

During the FIR plans

In between FIR and Ad.

FOR

When placing material

I do not know.

The day before seeding :)

prior to seeding

right before seeding, because that's when the subcontractor finds out they can't find the required seeds

During prime time of seeding season.

I do not know.

At the time of placement.

The end of project

Precon

Have not been involved with this

At the end of the construction project primarily for ease of access. Sometimes at the mid phase for alternate blanket systems in hopes of getting that phase re-veg prior to the end of the project.

Late

Between FOR and Ad.

Near time when revegetation work is to begin.

Typically right before soil prep and seeding, when attentions are held firmly on that aspect of the project.

enviro precon

Early in the project, after the pre-con or during the environmental pre-con

The subcontractors usually want to hydroseed everything instead of drilling, because hydroseeding is faster. There have also been requests to use their own mix of soil conditioner.

The most often requested change is allowing weed free straw instead of weed free hay. This request usually happens later in the construction phase.

Construction: At Preconstruction Conference if any difficulty is identified Contractor in procuring one or more of the specified seed varieties. Or: In the late fall if questions arise about completing seeding work ahead of consistent ground freeze.

## 19. In regards to revegetation, what do you think would improve revegetation performance?

After project acceptance CDOT Maintenance should take over watering and maintenance of revegetation areas. Often the Contractor moves on to other projects and maintenance is not a priority or sub-contractors responsible for maintenance go out of business. The loss the Contractor may take in CDOT not releasing retainage because landscape maintenance wasn't done is usually less money then the Contractor would have to put out in Labor and Materials to maintain revegetation so there is no incentive to perform maintenance.

separate contracts, or not holding all retainage until re-veg.

More rain.

CDOT's mowing and sprinkler maintenance policies have changed in the past year. Mowing only on 4' swath off behind roadway, and no special crews to maintain irrigation systems. To improve would be to change this direction. It is hard to get a contractor to adhere to our standards when the areas will become weeds.

If the soil was loosened, amendments (compost) incorporated, and seeding done properly. I.e. follow the specs.

Weather

This varies a large amount depending on the site. Steepness of slopes, less-than-infertile soil types, month of year that soil prep and seeding occurs, busy schedule of all seeding subcontractors trying to complete seeding on CDOT projects within the seasonal seeding restrictions, and method and type of fertilization used. Best times to install the full compliment of revegetation efforts is just after frost leaves in March or April and again in the fall as close to September 15 as practical. Depending on rain in the plains counties, seeding between August 15 and September 15 would be a good bet for success if permitted.

A more detailed plan and clearer specifications to Contractor's explaining the revegetation process.

N/A

.

Other than watering the seeding there is no way to improve the process it is up to nature.

Careful performance of soil conditioning or watch weather services (seed couple of days before raining).

Not really sure about this

Training on soil preparation and seeding. Most of use running projects know structures, earthwork, HMA and concrete. Seeding is usually the last thing done on a project which allows no time to see if the project is revegetation is working. It would be nice to hold a Contract open to ensure revegatation is working for a year but this creates problems with project close outs and finals.

I don't know.

Post install watering/maintenance.

Increase the application rate of seeds placed. The same with conditioning/fertilizer.

Separate re-vegetation contracts whose only goal is re-vegetation. On smaller projects that have smaller disturbance areas seeding/mulching is often one of the last items performed. CDOT Construction Contracts do not have a monitor re-vegetation time frame after all other work is complete.

NA

follow up by separate, specific contract

Honestly, I think the landscape architects need to understand each project and project location better. In addition, the designer and the landscape architect need to work closer together for a revegetation plan. Just recently had a project that had an embankment material to build up additional lanes, and the plan was to just add soil conditioner and seed. Well, embankment material can be up to a 2' minus material. The specification that addresses soil preparation requires a 4" minus material for seeding. So I had a dirt contractor satisfy their contract, which made it impossible for the seeding contractor to satisfy their contract.

My most recent project had an extended list of criteria to meet. I hired a biologist to ensure all the criteria were being met. She performed the transects for the basis of established vegetation and documented all species of plant for pre-construction activities. She ensures that the Landscapers are in compliance with our specs. It has been very helpful because she knows the products, installation guidelines and has been very helpful in dealing with the Landscapers. To date the plantings have been very successful with her oversight. On future projects I will be staffing my project team with a Biologist.

Better nurse crop seeding.

Multiple factors and it depends on the project time of year, amount of water that year.

*Stop LA/designers practice of "landscape restoration by Force Account" as a catch all for re-vegetation/ landscape restoration. Primes resent the use of F/A and it makes it more complicated for prime to sub in advance to a specialty (F/A is a non-biddable item). *Helpful when re-vegetation it is a biddable item which by specification clearly requires success. *A separate contract. At a minimum the re-vegetation / landscape restoration should be "framed" as a easily sub-contactable item. Primes often do not give re-vegetation priority since it is typically such a small part of a large contract. If were a sub- it could be a major item of the sub-contract. *And provide more CDOT support; CDOT LA / Environmental are often unavailable or too busy for consult / meetings/ field visits.

Water

Project scheduleing

We should either have the Contractor do temp stabilization and do the actual seeding on another contract, so it doesn't mess with schedule or get seeded in January, or we should require that the Contractor hold the permit until the 70% growth is complete, and pay stabilization for each area only once, so there is an incentive to get it correct the first time. To pay the Contractor numerous times for the same area is completely illogical.

Enforcing seed methodologies more strictly. This could possibly include the PM and the CDOT Landscape Arch.

Removing the spec that states slopes have to be seeded within 7 days of being finished. It makes more sense to seed in the appropriate time frame of the year rather than just 7 days after a slope is finished.

Planting at the correct time, most Contractors want to plant when ever they want. More stringent specs nay be required.

I think overseeding to ensure stable growth is better than having to come back if the exact amount of seed coverage doesn't take.

Straw/coconut blankets everywhere, if not a HUGE area.

Ensuring the revegetation subcontractor knows what he is doing.

Don't know

Better topsoil

Denying contractors/subcontractors with a poor performance record and bad reputation from working on CDOT projects.

Scheduled Milestones where the Contractor and CDOT representative meet on site and review progress

The seeds seem to be okay in general, but contractors seem to have problems with soil preparation and soil conditioning. Perhaps moving soil additives to the APL list instead of having just general material compliance might be an easier way to ensure quality materials are being used.

I don't know. It depends on the project.

It depends on the size of the project and the number of inspectors on the project site. If there is a small staff and there are two operations such as paving and seeding going on at the same time most of the time the paving will be the higher risk operation and we have to hope the seeding contractor is honest and does the job according to CDOT specs. I would have to say the biggest improvement would be to re-staff the construction side to cover all of the work. If we don't have the people we cannot do the work. Another improvement could be to hire a Regional Inspector (specialist) to oversee all of the CDOT conditioning, seeding and mulching operations. The Sub-contractors would have to schedule the work through the Environmental office in advance to the company arriving on site.

Write a specification to amend the topsoil on the project if not imported from off the project. Specification should have procedures the contractor needs to adhere to.

Relax 48 hour timeframe, contractors cover whatever they can with blanket so they have stabilzation but not permanent growth.

import fertile topsoil to promote healthy growth

- Choosing the correct seed mix for the environment & Conditions - Good top soil ( It is a challenge in some areas of Colorado) - Water - Protect and avoid erosion of seeded area

weather conditions

It is mostly based on the weather. Ask any farmer. Sometimes we get lucky, sometimes not.

Diligence in maintaining and supporting vegetation in the early stages, rather than just planting and leaving.

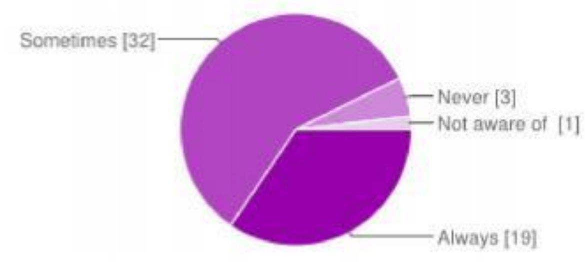
Complete soil testing as part of the SWMP design so prescriptive soil conditioning could be included in the competitive bid process for the project. Always salvage and protect top soil during construction. Develop soil chemistry and compaction testing that must be completed prior to allowing any seeding on the project to start. Do not allow seeding outside of the recommend times of the year. Either extend the project closeout date or remove seeding from the scope of work.

I think we need to water seeded areas until the seed pops and plants/grasses are established. In remote areas we are at the mercy of mother nature and often endure seasonal drought. We continue to return to these remote projects that do not have irrigation and spend considerable funds reseeding them and site back hoping for moisture. If moisture doesn't come, we do it again! Doesn't make sense to me. If we would pay the Contractor to regularly water freshly seeded areas until they are established, we could close out projects and stormwater permits in a reasonably timely manner.

look at the existing vegetation that is flourishing the most and go with that plant, because some of the seeds won't grow with the type of soil that is present.

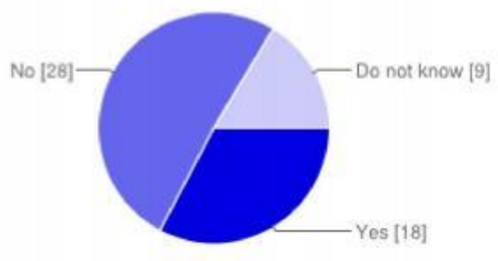
Require all seeding to be hydroseeded and hydromulched and eliminate hay and stray mulch. Often times the contractor will request higher prices as there is typically a shortage of weed free hay in Colorado. Stray has not been the preferred mulch per our environmental erosion control specialists. This commodity increases delays and overall costs to projects. The % growth specification for final acceptance should not exist since the work is installed and inspected per our specifications. Colorado presents various environment that our standard specifications do not address and does not work in certain instances.

## 20. Do you refer to the CDOT references, Erosion Control and Stormwater Quality Guide or Field Guide?



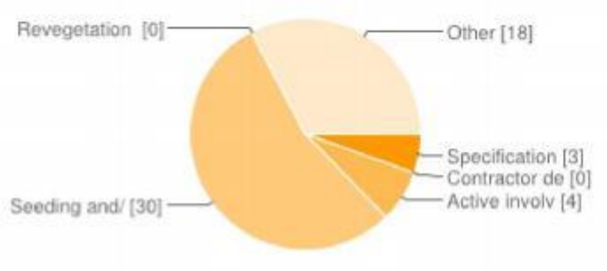
| | | |
|---|---|---|
| Always | **19** | 35% |
| Sometimes | **32** | 58% |
| Never | **3** | 5% |
| Not aware of guide | **1** | 2% |

## 21. CDOT provides a Regional Water Quality Manager to conduct a MAR (Monthly Audit Review). In addition to this support, does CDOT need to have landscape architects assist or oversee soil prep and seeding?



| | | |
|---|---|---|
| Yes | **18** | 33% |
| No | **28** | 51% |
| Do not know | **9** | 16% |

## 22. On past projects, when revegetation was highly successful what was the main reason?



| | | |
|---|---|---|
| Specifications were followed | **3** | 5% |
| Contractor deviation from specifications were beneficial | **0** | 0% |
| Active involvement from CDOT landscape architects or environmental specialists | **4** | 7% |
| Seeding and/or vegetation subcontractor(s) did their job well | **30** | 55% |
| Revegetation was a high priority | **0** | 0% |
| Other | **18** | 33% |

### 23. On past projects, when revegetation was mostly unsuccessful what was the main reason for the failure?

| | | |
|---|---|---|
| Specifications were not followed | **3** | 5% |
| Specifications were followed, but not sufficient to revegetate successfully | **11** | 20% |
| Not enough involvement from CDOT landscape architects or environmental specialists | **2** | 4% |
| Not enough resources | **3** | 5% |
| Revegetation is not a priority | **2** | 4% |
| Seeding and/or vegetation subcontractor(s) did not do their job well | **17** | 31% |
| Other | **17** | 31% |

## Number of daily responses

# Appendix I: Water Quality Permit Transfer to Maintenance Punchlist

# Water Quality Permit Transfer to Maintenance Punchlist

| **Item** | **Additional Actions Needed?** | **Location** | **Comments** |
|---|---|---|---|
| **Erosion and Sediment Sources** | | | |
| Are there signs of ***erosion*** ? | | | |
| Are there signs of ***sedimentation*** ? | | | |
| Do the ***outfalls*** need to be cleaned? | | | |
| Is there sediment in the ***inlets*** ? | | | |
| **Pollutants and Controls (BMP)** | | | |
| Is the particular pollutant missing a BMP? | | | |
| Has the BMP(s) been maintained properly? | | | |
| Has an incorrect BMP been used for the particular pollutant? | | | |
| Are there ***stockpiles*** needing to be removed? | | | |
| Does the ***concrete washout*** need to be removed? | | | |
| Are there signs of ***spills (including stains)*** on site that are not controlled? | | | |
| Are there signs of ***concrete, trash/debris*** or other pollutants not belonging on site? | | | |
| **BMPs** | | | |
| Are there any ***non-standard BMPs*** ? If so, is there a non-standard spec available? | | | |
| Do the ***perimeter controls*** need to be maintained or removed? | | | |
| Do the BMPs within ***channelized flows*** need to be maintained or removed? | | | |
| Do the BMPs on ***sheet flows*** need to be maintained or removed? | | | |
| Do the ***inlet protectors*** need to be maintained or removed? | | | |
| Are ***additional BMPs*** needed? | | | |
| Are there BMPs that need to be ***removed*** ? | | | |
| Are there any ***vehicle tracking pads*** that need to be removed? | | | |
| Are the ***permanent water quality features*** functioning incorrectly? | | | |

|  |  |  |  |
|---|---|---|---|
| **Stabilization Methods** |  |  |  |
| Are there any areas on site that do not have ***final stabilization methods*** applied? |  |  |  |
| Are the ***outfalls*** lacking stabilization? |  |  |  |
| Are there any areas that appear to need ***rework or additional work*** ? |  |  |  |
| Are there areas that that the soil is compacted and need the ***soil loosened or roughened*** to promote vegetation growth? |  |  |  |
| Is the ***stabilizer*** (Ex. mulch, tackifier, etc.) in need of repair? |  |  |  |
| Are there areas with the soil stabilizer (Ex. mulch, tackifier, etc.) ***disturbed*** that needs to be reapplied? |  |  |  |
| **Questions for PE/ECS** |  |  |  |
| Are there any wetlands on or adjacent to site? |  |  |  |
| Are there any areas with special maintenance needs? |  |  |  |
| Are there any problem areas that will need extra attention under maintenance control? |  |  |  |
| Is there any advice that PE or ECS can give about project? |  |  |  |
| Are there any sensitive areas? |  |  |  |
| Are there any endangered or threatened species noted on or adjacent to the site? |  |  |  |
| Is there any specific information on particular BMPs on site, including soil binders, tackifiers and/or sprayon products? |  |  |  |
| Are there any major areas of site run on, ground water or seasonal flows on site? |  |  |  |
| Is there any additional work to be conducted after today? |  |  |  |

**Note: For successful project permit transfer from Engineering to CDOT Maintenance, all answers (except those listed under Questions for PE/ECS) should be answered "no" or have a corrective action associated in the comment section.**

# Appendix J: Economic Benefits of Completing Reclamation Successfully the First Time for Oil & Gas Sites

# THE ECONOMIC BENEFITS OF COMPLETING RECLAMATION SUCCESSFULLY THE FIRST TIME FOR OIL & GAS SITES

PRESENTED:

INTERNATIONAL EROSION CONTROL ASSOCIATION EC10 DALLAS, TX

FEBRUARY, 18TH 2010

**David Chenoweth, David Holland, Gerald Jacob,**

**Lindsey Kruckenberg, John Rizza and Bryan Whiteley**

# BIOGRAPHICAL SKETCH

## *David Chenoweth*

Mr. Chenoweth, a Certified Professional Soil Scientist, started his career with ARCO Coal Company as a soil and environmental scientist completing work on surface and underground mines in the western U.S. Mr. Chenoweth founded Western States Reclamation. Inc. in 1983; He has over 31 years of experience in soil science, revegetation planning/construction, land restoration, land use planning, and environmental permitting. He has written revegetation training manuals and conducted stormwater management training seminars. Mr. Chenoweth has provided expert witness reports and testimony on cases involving natural resource damages including fire restoration erosion control evaluation. He has just completed a three year term as President of the American Society for Mining Reclamation.

## *David Holland*

Mr. Holland is currently the Environmental and Regulatory Manager, Rockies Asset Team for Pioneer Natural Resources USA, Inc. in Denver, Colorado. He is responsible for the environmental and regulatory compliance programs involving the company's oil and gas exploration and production in the Rockies. Mr. Holland currently oversees all reclamation and stormwater compliance activities in the Rockies. Prior to joining Pioneer, Mr. Holland was the Natural Resources Program Director for SWCA Environmental Consultants' in Salt Lake City, Utah focusing on environmental permitting and compliance services for the highway construction and oil and gas industries. Mr. Holland received his B.S. and M.S. degrees in Forest Management from Utah State University.

## *Gerald Jacob*

Mr. Jacob, Ph.D. is an Environmental Advisor to the senior management of Pioneer Natural Resources Inc. in Denver, Colorado. Previously he was the Environmental-Regulatory Manager responsible for all aspects of environmental monitoring and compliance for Pioneer's oil and gas operations in the Western U.S. and, prior to it's acquisition by Pioneer, served in a similar capacity with Evergreen Resources Inc. He has extensive experience in coalbed methane as well as conventional oil and gas operations. Dr. Jacob has degrees from the University of Chicago, Utah State University and the University of Colorado-Boulder.

## *Lindsey Kruckenberg*

Ms. Kruckenberg works for EnCana Oil & Gas as a Coordinator within the Surface Management team. The Surface Management team maintains disturbances created by EnCana in the Piceance Basin. The team maintains environmental compliance with regards to Reclamation, Stormwater, SPCC, Weed control, Pit/Net inspection, etc. Lindsey is involved in all phases of planning, implementation, interaction with regulatory agencies, monitoring, and reporting. She graduated from the University of Colorado with a Bachelors degree in Geology and has previous experience with remediation of soil and groundwater along with chemical analysis of soil, water, and air.

## *John Rizza*

John Rizza, is a Certified Arborist and Estimator for Western States Reclamation Inc. He has conducted research in relation to obtaining his Masters degree on reclaiming strip mine spoils in eastern Tennessee. John received his B.S. degree at Colorado State University where he focused on Forestry and Forest Reclamation. He has experience working in a variety of ecosystems throughout the U.S. John's innovative ideas have helped improve reclamation practices and promote healthy establishment of native vegetation on drastically disturbed sites.

*Bryan Whiteley*

Bryan Whiteley, Landscape Architect, has been recognized for his thoughtful construction, operations and maintenance cost management while delivering outstanding design solutions on many interdisciplinary design teams for major projects including *Leadership in Energy and Environmental Design* certified projects involving site selection, protection and restoration; water efficient landscaping and planting design, non-potable irrigation; stormwater management and construction activity pollution prevention plans. In 2005, Bryan founded LandStewards™ and set new precedence in reclamation, stormwater and VRM within the energy industry. Bryan's topsoil conservation strategies have been adopted by the BLM for oil, gas and geothermal development. In 2009, Bryan accepted a new position with EnCana as their Piceance Basin Surface Management Coordinator managing 900,000 acres of development.

# THE ECONOMIC BENEFITS OF COMPLETING RECLAMATION SUCCESSFULLY THE FIRST TIME FOR OIL & GAS SITES

*David Chenoweth, David Holland, Gerald Jacob, Lindsey Kruckenberg, Brian Whiteley*

## ABSTRACT

Environmental Managers employed by energy companies are often plagued with the lack of adequate cost data to support appropriate budgets for successful initial reclamation programs. Insufficient budgeting and improper initial reclamation for drill pads and access roads can result in higher overall operating cost and lower net profits over the life of the well. Pioneer Natural Resources and EnCana Oil and Gas Inc. have provided actual cost data for this case study and information from operations in the Piceance Basin and Raton Basin of Colorado. Minimizing reclamation and maintenance costs over the life of the well by properly budgeting and planning initial reclamation activities is essential to ensure cost savings. Reclamation failures can result in a 50% cost increase over initiating proper reclamation techniques from project implementation. The economic impacts associated with the direct costs of additional earthwork for sediment clean up and re-grading, importing topsoil or applying soil amendments when poor soil conditions generate initial revegetation failures, re-seeding, re-installation of erosion control products, and weed control are significant. Operators can expect to spend upwards of $20,000 on sites where initial reclamation programs have failed. Additionally, hidden indirect costs, which are difficult to quantify, include environmental manager and consultant time to coordinate reclamation work that needs to be redone, potential agency fines for storm water management violations, and potential lost opportunity cost due to poor agency and landowner relationships that delay mineral extraction. Developing more effective programs to track these reclamation and stormwater management costs would benefit operators in the long term. Providing reasonable estimates for reclamation activities on sites to be capitalized up front would ensure resource protection.

## I. INTRODUCTION

At the onset of the Phase II Storm Water Quality Regulations enforcement by the Environmental Protection Agency (EPA) many energy companies found their storm water management and reclamation programs lacking compliance with the new laws. Numerous energy companies learned the hard way, through hefty fines, what non-compliance with the storm water regulations can mean. Environmental Managers were grappling with budget constraints as well as what the constituents of a reclamation and storm water management program that can comply with state and federal laws. Western States Reclamation has worked for both Pioneer Natural Resources and EnCana Oil and Gas Inc. as a reclamation and storm water management contractor. Western States has witnessed the growth curve that oil & gas companies have gone through in trying to develop storm water management and reclamation programs. In a time of low natural gas prices the cost of storm water management and reclamation programs are being scrutinized by upper management. Environmental Managers with energy companies need to establish budgets that are adequate for successful reclamation and meet the requirements of federal and state regulatory agencies. Inadequate unsuccessful reclamation programs can result in an exponential increase in the comparative cost to retrofit sites which may exceed the costs of implementing a more thorough and successful reclamation program the first time around.

The purpose of this case study is to compare the cost of successfully reclaiming a site at the outset compared to the cost to retrofit an unsuccessfully reclaimed site. Western States Reclamation encouraged environmental managers with both Pioneer and EnCana to compile costs for previous reclamation projects. These costs could then be evaluated to determine the cost of successful reclamation work against the costs associated with retrofitting inadequately reclaimed sites.

While the cost data provided in this case study can be considered subjective it still provides evidence that there are economic benefits to performing reclamation right the first time. This case study also shows the importance of Environmental Managers setting up a system for cost data collection to establish credible reclamation budgets. Poor quality reclamation programs could result in higher lease operating expenses – a critical metric in the oil & gas industry. Western States Reclamation, Pioneer, and EnCana established a list of several key factors that are needed for successful reclamation projects:

- Locate facilities and access roads to minimize slope and stormwater run-on.
- Identify areas for potential topsoil salvage and establish a replacement plan for interim and final reclamation.
- Properly grade pads and install terraces, berms, benches, etc. to reduce sediment loading during interim and final reclamation.
- Apply the proper types and amounts of soil amendments to the soil when topsoil is lacking or poor in quality.
- Perform proper soil tillage to loosen compaction.
- Design proper seed mixtures and application rates.
- Adequately install and maintain BMPs and erosion control devices until the desired vegetation achieves self sustaining cover.
- Complete mechanical and chemical weed control for as long as needed to control noxious weeds.
- Construction supervision & monitoring so that all parties have an understanding of how their work fits in the overall project design.

Poor quality reclamation work results in cost increases to reconstruct and reclaim these sites. Experience demonstrates that most reclamation failures can be traced back to three factors; the lack of available quality seedbed materials (topsoil), the lack of implementing proper storm water BMPs, and the lack of clear upfront project design and follow-up performance supervision. Poor quality soils are typically the most erodible. Poor quality soils typically support less final vegetative cover for long term erosion control and significantly more weed species growth than desirable grasses or forbs. Improperly implementing BMPs can result in undesirable protection for newly seeded or planted vegetation. This ultimately creates poor vegetative health and delays the establishment of a desirable self sustaining cover. Failure to address erosion and sediment issues in the design of any site reclamation and properly supervising their execution can greatly increase the cost of reclamation programs.

### i. Commonly Associated Direct Costs

Direct costs for reclamation and stormwater management failures include the following:

- Retrieving sediment from erosion and sediment events, including off-site.
- Replacing sediment or other suitable materials in washout areas.
- Regrading
- Reseeding
- Replacing and possibly adding more BMPs to avoid future washouts.
- Extending the duration for weed management activities.
- Additional maintenance and inspection costs due to restarting the reclamation clock.

### ii. Commonly Associated Indirect Costs

There are many indirect costs that energy companies often may not recognize as significant in the cost of reclamation and stormwater management failures which include:

- Increased staff and consultant time to deal with sediment and erosion issues and redoing reclamation work and inspections
- Tarnished Agency and Landowner relationships
- Potential regulatory non-compliance

The costs associated with reclamation may be a relatively small percentage of the capital cost to drill and develop an oil and gas well. However, reclamation can become a significant factor in the operating expenses associated with a well, particularly on older wells where less sophisticated reclamation measures were used. Often, issues in Lease Operating Expense (LOE), a metric commonly used in the oil and gas industry, are followed closely by managers and financial analysts as indicators of profitability. LOE per unit of oil or gas produced is often used as an indicator of an operator's efficiency. Unexpected inputs and resource allocation can lead to some level of impact to profitability.

This case history assesses the varying successes of reclamation and storm water management efforts experienced by Pioneer Natural Resources environmental staff operations in southeast Colorado. Also investigated is the Piceance Basin operation near Rifle, Colorado managed by EnCana environmental staff. These case study examples will demonstrate the financial advantages of reclamation planning in the early stages to ensure long term success. Evidence suggests that improper reclamation, storm water management, and associated budget programs could significantly reduce company profits over time. Properly designing and implementing BMPs, site monitoring, and progressive management will enable managers to successfully reclaim surfaces which will reduce waste and costs.

## II. CHALLENGES AND PROPOSED SOLUTIONS FOR INCREASING RECLAMATION SUCCESS ON DRILL PADS AND ACCESS ROADS

### i. Initial Planning and Site Surveys

An initial site survey conducted by environmental and engineering personnel should be the first step in the reclamation process to determine optimum routing of access roads and pad location for successful interim and final reclamation. Degree of slopes to be encountered, watershed size, exiting vegetation species inventory, and soil resources present should be evaluated and considered in the planning process. Operators have found that proper site selection is essential to avoid costly site development and reclamation issues.

Many of the challenges related to site selection are due to topographic variation including slope, drainage features, and subsurface material composition. Often, operators must implement a variety of techniques to address site concerns. Whenever practical, benching or terracing should occur on steep slope areas. Every effort should be made to retrieve viable topsoil during road and pad construction. Often, operators and engineers feel they have ample knowledge of what topsoil is by simply looking at soil color. However, proper identification of possible topsoil materials requires collecting and sampling an adequate number of sample sites. The sample data has to be evaluated for suitability as topsoil by rating the material according to standards that have been published by the U.S. Department of Agriculture and State Agencies such as Department of Environmental Quality. Currently, managers are modifying their practices to conduct their activities within the new Colorado Oil and Gas Conservation Commission (COGCC) rules. Background samples are an important part of conducting development activities. Program managers are continually adding sampling parameters for measuring soil vitality. Soil samples are typically rated by parameter as to good, fair, or unsuitable material. Any indication of unsuitable soil ratings may be cause for a soil scientist to reject material as topsoil for salvage. When seedbed quality material does not exist on site for use in reclamation, a variety of soil amendments may be utilized to build a suitable soil from local materials. Amending soil located in close proximity of the work site to create suitable growth media should be compared to the cost of importing topsoil. Management teams are implementing programs which utilize perimeter windrowing for topsoil conservation. The windrow is seeded and hydraulic erosion control mulch is applied almost immediately after its construction. The windrow minimizes the slope length facing the exterior edge of the disturbed area. Ideally this maximizes the topsoil surface area which helps to maintain its viability. This technique reduces the overall quantity of erosion control BMPs utilized for a well site, contains and diverts stormwater within the disturbance, and maintains topsoil adjacent to its previous position. Suitable quality seedbed material is the most critical building block to achieving successful reclamation on the first attempt.

### ii. Topsoil Placement and Site Re-grading

The sites encountered in this case study often lack salvageable topsoil material. Operators are faced with thin soils which are often poor in nutrient content and lacking in organic matter. The significant amount of course fragments occurring on these sites also impedes the ability to salvage soils. Operators must account for the creation of adequate topsoil or topsoil substitute materials early in the planning process. Seedbed quality material placement followed by site regrading of disturbed areas should be completed in a manner which limits water run-on and runoff. Geomorphic landforming and earthen hydrological controls are utilized to manage water run-on, runoff, to reduce slope potential for erosion, and contain sediment. Terracing and berming on disturbed areas are a few methods utilized to effectively control water erosion. Channelizing flow from disturbed areas and routing through adequately sized detention ponds are also effective methods of treating water flow to prevent sedimentation and reduce the need for re-grading operations. When these landforms and drainage controls are properly constructed with suitable subsoils to achieve proper grade and sediment containment, they are then ready for topsoil spreading. When utilizing perimeter windrows for topsoil conservation, the topsoil is easily placed on the adjacent subsoils limiting compaction and potential losses.

### iii. Seed Mixture Design

Seed mixtures, seeding rates, and seeding methods are all very important elements for successful reclamation practices. Considerations for the actual seed mixture should include species of grasses, forbs, and shrubs that are common to the area. Also, the intended land use after final reclamation is completed should be considered and related to vegetative species selection. For example, if managers choose livestock grazing as the future land use, the vegetative cover mix should focus on a balance of warm season and cool season grasses which are palatable. Wildlife habitat should include native forbs and shrubs for browse and cover. Forb species are important for game birds such as pheasants, turkey, quail or grouse. These native species will attract insects as a food source for young chicks and in turn benefit overall site establishment. Selecting the appropriate seeding rates represents both an art and a science. Educating landowners to the timeline for vegetative establishment and addressing their concerns during the planning process is imperative to creating a cooperative working environment.

Seed mixture designs must take into consideration items such as ease of establishment of individual species, number of seeds per pound per species, and aggressiveness of individual species. Grass species can vary greatly in their number of seeds per pound. For example, Buffalo Grass has 56,000 seed per pound and Sand dropseed has 5,298,000 seeds per pound. A targeted goal for planting seeds per square foot according to most revegetation experts ranges from 75 seeds per square foot up to

140 seeds per square foot. Regulatory agencies often specify required minimum seeds per square foot depending on site conditions and seeding type. Increasing the number of seeds per square foot is based on the risk of loosing seed to water erosion on steep hill sides or wind erosion in high wind prone areas.

To promote species diversity and sustainability, managers should design seed mixtures containing 4 to 10 different native species. The number of pounds of individual species should be based on a relatively equal number of seeds per square foot while taking into consideration ease of establishment and interspecies competition. Having a number of species in the mixture will promote diversity in the final vegetative cover and will reduce the risk of revegetation failure. The amount of time needed for certain species to establish can play a significant role in site stabilization. Often, native species take 2 to 3 growing seasons to achieve an adequate amount of cover. Managers need to account for this and recognize the increased risk associated with utilizing native species. Any expert in the revegetation industry knows that there are no absolutes in designing a seed mixture.

A seed mixture at a minimum will consist of native grasses and forbs. As previously mentioned at least three grass species should be in any revegetation seed mixture. The operator (such as EnCana), landowner (either private landowner or federal agencies such as the Forest Service or BLM), and Revegetation Specialist typically consult with one another to determine what the seed mixture should contain. These individuals or organization will determine if the seed mixture should contain only grasses or whether shrub and forbs seed should be added to the seed mixture as well. Typically cost of seed is a driving factor on deciding if these species are added to a seed mixture.

### iv. Seeding Methods

Common options for seeding methods include drill seeding, hand and machine broadcasting, and hydroseeding. Drill seeding is considered the most reliable method of seeding since there is more control over seed depth placement and seed covering with soil (Figure 1). However, drill seeding is not always possible on drill pads and access roads since steep slopes and rocky terrain prohibit access with equipment. Hand broadcasting or hydroseeding are typically used where drill seeding is not practical. However, these methods are often costly and exhibit limited success. Sources of water for hydroseeding operations can be difficult to obtain and increase the cost of reclamation. Managers need to be aware of the costs and benefits related to each method of seeding to make an informed decision. Regardless of which of these practices are used, it is important that the seed is properly covered with soil by hand raking, slope chaining, or harrowing.

Figure 1: Proper reclamation of access roads in the Raton Basin before (2005) and after (2008)

Drill seeders should be calibrated for use on a small area before all seeding is completed. Most manufacturers of drill seeding equipment can provide general guidelines as to the amount of seed output by seed box for flowable seeds versus trashy seeds. Calibration will help ensure that the proper amount of Pure Live Seed (PLS) is planted. All drill seeding should be completed parallel to slopes or on the slope contour. Drill seeding up and down a slope can result in accelerating erosion after rainfall since the indentations from the drill rows help to concentrate flow and accelerate soil movement down hill. It is recommended to plant most native grass and forbs species to a depth of ¼ inch for optimal germination.

Broadcast seeding is typically done where seeding areas prohibit safe operation of a farm tractor, access is limited, scope of work is small or the soil surface is covered with large rock that cannot be economically removed. Hand seeding may be needed in small, tight access areas where machinery cannot effectively operate. Broadcast seeding is performed using hand seeders or tractor mounted spreaders. Broadcast spreaders typically spread an even swath of seed onto the soil surface. Broadcast seeding by hand or machine alone will not typically provide good results unless the seed is covered with soil. Broadcast seeding with a tractor should be followed by using a flex harrow to cover the seed with soil. Hand broadcast seeding should be followed by hand raking with a hard tine rake. In both cases the seed should not be raked deeper than ½ inch into the ground. And in all cases, the chance for broadcasted seed germination is greatly increased when followed by mulch application.

Often operators utilize hydraulic applications of seed on pads and roadways. The operator will mix the seed, amendments, required tackifiers, and hydromulch in the tanker. The objective of using the hydraulic pressure of the machine is to use enough force to shoot or push the seed into the ground. If the seed is not adequately covered with soil, hand raking of the area or slope harrowing should be employed.

### v. Mulch and Erosion Control Fabrics

Surface mulch and erosion control blankets are needed to conserve soil moisture and serve as BMPs to control erosion. Lack of proper erosion control can result in seed being washed away before it germinates. Mulch materials also promote increased moisture infiltration from rain and snow, cool the soil surface, and provide valuable soil organic matter to increase soil structure. Mulch considerations include conventional hay/straw mulch and hydromulch. Innovative products being applied to meet the needs of challenging sites include Bonded Fiber Matrix (BFM), and Flexible Growth Medium (FGM). These products tend to be more expensive and create application difficulties on certain sites. Experienced operators must employ techniques to ensure adequate seed germination and soil stabilization. In many circumstances, erosion control blankets can be an effective way to control sediment movement. On the sites investigated by this case study, operators have determined that these blankets are most useful when used in place of mulches on steep uniform slope areas, drainage areas, and constructed diversion channels. These products come in a number of different fabric ratings to control erosion. Some examples include excelsior blankets, straw blankets, straw coconut blend blankets, coconut blanket, and geotextile blankets for more permanent erosion control. Mulches and blankets need to be complemented with other BMPs to ensure proper erosion control and comply with state and local agency requirements for disturbed construction sites.

Erosion Control Mulch (ECM) is hydraulically-applied, flexible erosion control blanket composed of long strand, thermally refined wood fibers, crimped, interlocking fibers and performance enhancing additives. Operators utilize ECM that requires no curing time and when applied forms an intimate bond with the soil surface to create a continuous, porous, absorbent, and erosion resistant blanket that allows for rapid germination and accelerated plant growth. Many applicators have determined specifications for the ECM application rates and techniques on a site specific basis to ensure soil and vegetation stabilization.

### vi. Structural BMPs

Some of the structural BMPs that are available on the market include erosion logs, straw wattles, silt fence (including wire backed fence), erosion bales, and rock socks. Constructed physical devices can include wood logs placed perpendicular to the slope, wood slash piles in drainages to slow water flow, diversions, terraces, rock check dams, and many others. On disturbed sites, these products can create significant maintenance challenges when failures occur. Combining different techniques is an effective way to utilize the benefits of structural devices. Areas with concentrated flows created by landforming can receive erosion control blanket with wattle check dams. Riprap can also be applied to containment outlets to limit impacts caused by concentrated flows. These types of stabilization techniques are very effective methods for reducing soil loss and they are also cost effective due to low initial cost and reduced maintenance requirements.

## VII. MAINTENANCE AND MONITORING

The objective of surface management programs is to utilize a wide range of tools and management practices to establish a diverse self sustaining mosaic of vegetation cover that exceeds regulatory agency compliance requirements and provides a new precedent for the visual resource, stormwater management, revegetation, and productive land use. Establishment successes are often achieved by early planning for the long term. Maintenance and monitoring programs developed from project implementation will benefit site establishment and sustainability. Maintenance of seeded areas includes weed control, erosion control, and touch up seeding. Most newly seeded sites require these maintenance operations during the first growing season to help insure successful revegetation. Observing the site in regularly scheduled intervals and evaluating changes will allow proactive management to reduce the need for unexpected repairs and erosion control additions.

### i. Weed Control

Managers must address weed control concerns by treatment consisting of mechanical methods such as hand cutting and removal, weed eating, and bush hog mowing. Ideally, operators should mow or cut weeds when twenty percent (20%) canopy cover for any surface area is achieved. Mechanical weed control is typically used the first growing season and often needs to be completed twice per year. If weed species continue to be a problem for the native grasses after a 12 month grow-in period control techniques shift to use of approved herbicide applications

### ii. Touch-up Seeding

A consensus among local ecologist has shown that two healthy seedlings per square foot after one growing season are typically adequate for successful reclamation. Thus, any areas not containing at least two seedlings per square foot should be evaluated and reseeded. Most surface management programs are performance based. Revegetation results are directly related to the quality of the site design, earthwork, seeding, mulching and stormwater applications. A lack of attention to detail during earthwork and soil preparation adversely affects the quality of the visual resource, stormwater management, revegetation and ultimately lengthens the maintenance cycle. Each phase of site activities can adversely affect the following phase if implemented poorly.

### iii. BMP Repairs, Re-grading, and Additions

Inspections and maintenance are an extremely important part of the stormwater management process. Inspectors ensure controls are constructed or applied in accordance with governing specifications or good engineering practices. The goal is to minimize the potential for inadvertent removal or disturbance of BMPs and to prevent the off site transport of sediment and other pollutants. Maintenance activities will ensure that all control measures are functioning at optimum levels and that all procedures and techniques will be in proper working order during a runoff event or spill condition.

When inspections determine that repairing areas where rill or gully erosion has occurred, immediate action is required. These repairs will increase financial and resource inputs long past well construction completion. When channel erosion is severe enough to warrant re-grading, the vegetative cover will also have to be repaired. Seeding steep slopes and waiting to achieve the desired amount of cover increases the likelihood of additional site repairs. These reworked sites need to be inspected after every rainfall event or every two weeks. In certain situations, re-grading and reseeding have to be completed on a semiannual or annual basis as needed to make sure that the vegetative cover is progressing towards a self sustaining cover and 70% of background cover. These repairs can prove costly and will add to the time for site recovery.

## IV. LESSONS LEARNED

### i. Cost of Proper Reclamation Programs as Completed by EnCana and Pioneer Natural Resources

Both EnCana and Pioneer have experienced the learning curve of using less adapted reclamation techniques versus their site-specific reclamation practices that are currently on-going. Costs were compiled from EnCana and Pioneer Environmental staff for each major technique related to proper site reclamation activities (Table 1). These operators provided average costs by slope category for drill pads and access roads on a per acre basis for comparison. Steeper slopes accounted for an increase of approximately 25% over gentile grades for both operators.

***Table 1 - Estimated Costs of Proper Reclamation Practices on Drill Pads***

| | **EnCana - Piceance Basin** | | **Pioneer - Raton Basin** | |
|---|---|---|---|---|
| | <u>(2.1:1 to 3:1)</u> | <u>(1:1 to 2:1)</u> | <u>(2.1:1 to 3:1)</u> | <u>(1:1 to 2:1)</u> |
| <u>**Treatments**</u> | Cost per Acre | Cost per Acre | Cost per Acre | Cost per Acre |
| Lifespan Planning | $950 to $1,150 | $950 to $1,150 | $1,250 per acre | $1,500 per acre |
| Topsoil Conservation | $525 - $1,142 | $450 - $1,101 | $750 | $1,000 |
| Topsoil Replacement | $1,100 - $1,060 | $950 - $1,020 | | |
| Pad Re-grading | $1,224 - $1,632 | $1,224 - $1,632 | | |
| Landforming | $9,500.00 | $9,900.00 | All Inclusive, Drill Seeding w/ straw mulch, tackifier, BMPs $14,000 | All Inclusive, Hydroseed w/ Flexterra hydromulch, BMPs $17,000 |
| Soil Preparation | All Inclusive, Drill Seeding & Crimped Straw $2,620.00 | All Inclusive, Broadcast Seeding & Flexterra Mulch $7,015.00 | | |
| Soil Amendments | | | | |
| Seeding | | | | |
| Mulching | | | | |
| BMP's | $900.00 | $900.00 | | |
| Weed Control | $125.00 | $200.00 | $125 | $200 |
| **Total Costs** | **$16,944 to $18,129** | **$21,589 to $22,921** | **$16,125** | **$19,700** |

### ii. Estimated Costs of Low Budget Reclamation Practices on Drill Pads

In past times, operators often reclaimed sites with minimal inputs and disregarded revegetation standards and erosion control BMPs (Table 2). Sites were often reclaimed without adding any type of soil amendments or any type of tilling activities to create quality seedbed materials. Seeding was often conducted using aggressive forage species including perennial rye that were not drought tolerant but could be purchased at a relatively low cost and quickly achieve densely vegetated stands. Operators could spend as little as one to two percent of capital on reclamation activities under the old regime. That is compared to 5-8 percent of capital that is currently spent on reclamation.

***Table 2 - Estimated Costs of Low Budget Reclamation Practices on Drill Pads***

| | **EnCana - Piceance Basin** | | **Pioneer - Raton Basin** | |
|---|---|---|---|---|
| **Treatments** | (2.1:1 to 3:1) Cost per Acre | (1:1 to 2:1) Cost per Acre | (2.1:1 to 3:1) Cost per Acre | (1:1 to 2:1) Cost per Acre |
| Initial Planning | \$520 to \$570 | \$520 to \$570 | \$1,000 | \$1,000 |
| Topsoil Stockpiling | \$775 | \$625 | none | none |
| Topsoil Replacement | \$1,350 | \$1,250 | none | none |
| Pad Re-grading | \$1469 to \$2122 | \$1469 to \$2122 | \$1,000 | \$2,000 |
| Subsoil Contour Grading | \$11,100 | \$10,750 | none | none |
| Soil Preparation | none | none | minimal | minimal |
| Soil Amendments | none | none | none | none |
| Seeding | \$500 | \$500 | \$500 | \$500 |
| Mulching | none | none | none | none |
| BMP's | minimal non-structural | minimal non-structural | minimal non-structural | minimal non-structural |
| Weed Control | \$250 | \$400 | \$250 | \$400 |
| **Total Costs** | **\$15,964 to \$16,667** | **\$15,514 to \$16,217** | **\$2,750** | **\$3,900** |

### iii. Costs Associated with Unsuccessful Reclamation Programs

EnCana and Pioneer Environmental staff compiled costs associated with reclamation work that required redo treatments (Table 3). While redo cost can be very subjective, expert opinion and costs compiled by the three different companies (EnCana, Pioneer, and Western States) added to the credibility of the results. Redo work on these sites often ranges from \$20,000 to \$40,000 depending on the severity of site degradation and need for re-grading and reseeding. The addition and reworking of BMPs on these sites is another significant area of economic and resource input.

***Table 3 - Costs Associated with Reclamation Failures***

| | **EnCana - Piceance Basin** | | **Pioneer - Raton Basin** | |
|---|---|---|---|---|
| **Redo Treatments** | **(2.1:1 to 3:1) Cost per Acre** | **(1:1 to 2:1) Cost per Acre** | **(2.1:1 to 3:1) Cost per Acre** | **(1:1 to 2:1) Cost per Acre** |
| Sediment Clean Up | $500 to $1000 | $500 to $5,000 | $500 to $1,000 | $1,000 to $5,000 |
| Fill Placement | $500 to $1000 | $500 to $5,000 | $500 to $1,000 | $1,000 to $5,000 |
| Re-grading | $11,100 to $13,100 | $10,750 to $13,750 | $5,000 to $10,000 | $8,000 to $15,000 |
| Reseeding and Mulching | Drill Seeding & Crimped Straw<br>$2,620 | Broadcast Seeding & Flexterra Hydromulch<br>$8,017 | Drill Seed, Straw Mulch w/Tackifier<br>$2,000 | Hydroseed, Flexterra Hydromulch<br>$8,000 |
| Fix BMP's and Add More | $5,000 | $5,000 to $10,000 | $5,000 | $10,000 |
| 1 Year Extended Weed Control | $350 | $450 | $250 | $400 |
| **Total Costs** | **$20,070 to $23,070** | **$25,217 to $42,217** | **$13,250 to $19,250** | **$28,400 to $43,400** |

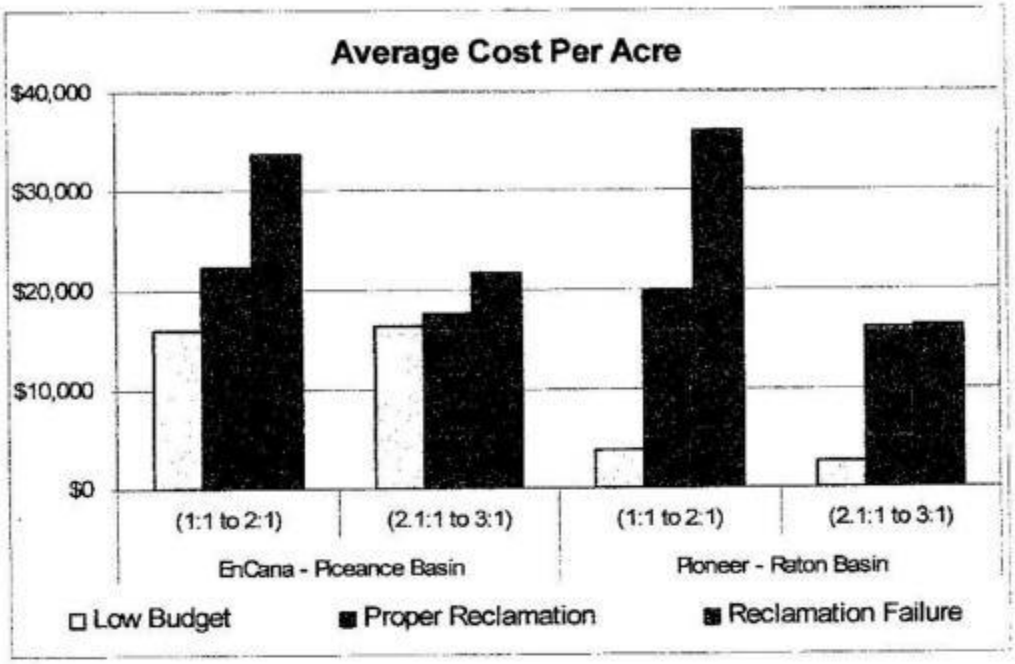
### iv. Indirect Cost Estimates Resulting from Unsuccessful Reclamation

EnCana and Pioneer were asked by Western States to provide estimates of indirect cost to handle storm water management issues with state agencies and reclamation issues with individual land owners. The categories were divided into estimates of regulatory fines on a per acre basis, administrative time to deal with land owner and state agency issues, and finally what potential lost opportunity could be for delayed mineral extraction especially during the peak pricing periods of 2007and 2008.

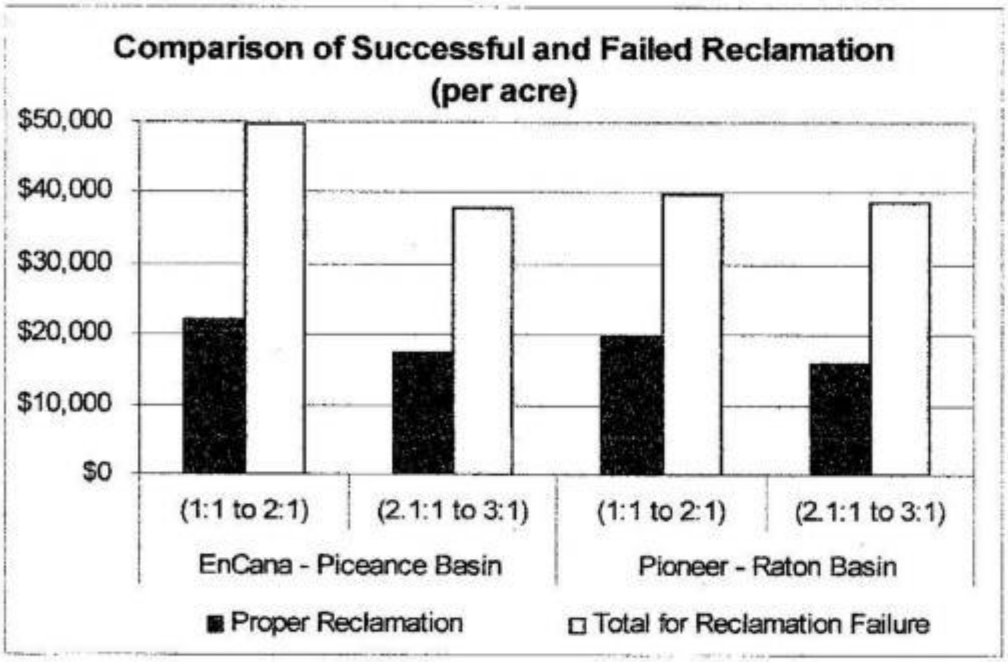
Calculating these costs proved to be very difficult since they were based on memory by EnCana and Pioneer Environmental staff. While the cost estimates are very subjective for indirect cost, they are conservative figures and have merit in being considered for illustrating to upper management the benefits of good reclamation programs. Upon further investigation of several example sites, we found that agency fines could range from $0.10 to $15 per acre depending on site conditions and other relevant factors. This is a significant total cost when considering both companies operate across several hundred thousand acres. We also found that a significant amount of time is spent by operators communicating with landowners or regulatory agency representatives about the deficiencies associated with poor reclamation. Administrative costs can range from $20,000 to $120,000 per year depending upon the amount and severity of conflicts. If effective initial site analysis and design are not adequately implemented environmental managers inherit additional-unneeded risk and additional cost over the lifetime of the asset. Again, although difficult to quantify, we can estimate the potential lost opportunity costs to be in the area of $1000 per acre in standard situations. Operators feel that linear disturbances after reclamation activities remains the highest surface management risk and most difficult to change.

## v. Cost Comparison of Successful to Unsuccessful Reclamation Work

Operators have found that any lack of attention to one detail adversely affects the others. Each component of the reclamation is interconnected and failure of one element causes failure of the entire reclamation program. Costs are significantly compounded when failures occur due to operators minimizing initial expenses for reclamation (Chart 1). Successful management of the landscape can only be achieved when planning for stormwater, revegetation, weed control, and reclamation over the lifespan of the assets. Poor stormwater design and topsoil conservation adversely affects revegetation which impacts future weed management. Poor reclamation design adversely affects operating and maintenance costs and public perception during the production lifespan of the asset.



When comparing the total cost of initial low budget reclamation and associated reclamation work due to site failure, we find that generally, the cost per acre is significantly higher than implementing adequate reclamation on the first attempt (Chart 2). Pioneer, being relatively youthful with respect to the data available for this case study, demonstrates similar trends as EnCana with respect to higher costs for steeper slope reclamation operations. EnCana has collected data on a much more intensive and larger area, approximately three times the area of Pioneer's operations. These experiences represent the norm for operators as they have adjusted their approach over time based on better tracking of reclamation and stormwater maintenance costs.



### vi. The need for Cost Data Through Annual Assessments of Reclamation and Stormwater Management Work

It became quite evident while preparing the case study that the previous years reclamation and storm water efforts needed to be evaluated on an annual basis to determine what practices were working the best and what redo work might be avoided in future efforts. In Pioneer's case cost allocation practices were recently altered to capture reclamation and stormwater efforts separately from traditional earthwork and well site construction costs.

Reclamation work has long been viewed as both an art and a science. There is no cookbook method to making sure that reclamation efforts are successful across a wide variety of sites found in company's area of operations. Site specific adjustments to reclamation and stormwater management programs should be expected since energy development covers a variety of different environmental factors and ecosystems that does not allow for a one practice fits all technique.

### vii. Time Saving Areas for better use in Reclamation Project planning and budgeting

All environmental managers agreed that a significant percentage of their time and their staff's time was spent on problem solving old stormwater management and reclamation issues which could have been better spent on new well sites and increased production. Also, time could be utilized to continually determine through site evaluations where reclamation efforts could be improved to reduce the need and cost impact of redo work. While the authors feel that the cost data provided was useful, more accurate data would be beneficial in the future to pin down the cost of successful reclamation. Proper reclamation cost data will help establish better program budgets and select better adapted practices. More reliable economic forecasting will provide better credibility for planning and budgeting reclamation programs.

## V. Conclusions

### i. Findings

In conclusion, even with subjective cost data supplied in this case study the authors feel that by using conservative figures there is significant proof that there are many economic benefits to proper reclamation work completed the first time around. When either operator had utilized the minimal input reclamation procedures of the past, the opportunity for failure was significantly higher and in turn the cost of redo work ends up costing the company much more money. Reclamation failures can result in a 50% cost increase over initiating proper reclamation techniques from project implementation. This is related to many factors including the lost opportunity of advancing and moving on to more lucrative sites. EnCana's numbers represented a much larger area and demonstrated that in the big picture, the costs of reclamation failure is much higher on steep slopes due in particular to site re-grading and seeding operations.

### ii. Future developments

Environmental managers have found that the accounting department should be involved in assessing reclamation program success. At this time most operators are tracking the project costs on an individual pad and associated access road basis. For the future, it is essential to track out-of-house contractor costs for reclamation and stormwater management activities as well as in-house staff time for handling reclamation tasks. Separate project costing codes are needed to track costs for original reclamation efforts against any redo work. As reclamation and storm water management programs are steadily improved, project costing should help illustrate these reductions in direct and indirect costs for problem sites. Most contractors are utilizing a job cost based accounting software system that tracks costs and profitability on an individual job basis. Thus, reclamation contractors may be able to provide assistance to energy companies on how to set up project costing programs. Developments in technology and data collection should allow managers to create custom programs adapted to company accounting software for ease of analysis.

# Appendix K: Revegetation Monitoring and Inspection Tool

# CDOT Revegetation Checklist

## Checklist Page 1

**General Information**

Contractors Name ______________________

Date of Inspection ______________________

Mileposts From __________ To ______________ Foreman ________________

QC Personel ______________________

Stage of Construction ______________________

**QC Items** **Comments**

***Storm water***

SWMP available ☐ ______________________

Erosional issues ☐ ______________________

Offsite veg inventory completed ☐ Percentage: __________ Transects: __________

Other: __________ ☐ ______________________

***Revegetation Plan***

REC available ☐ ______________________

IWM Plan avalialble ☐ ______________________

Offsite veg inventory completed ☐ Percentage: __________ Transects: __________

Other: __________ ☐ ______________________

**Topsoil** **Specified Depth** __________

Topsoil Salvaged ☐ ______________________

Topsoil Stockpile Segregated ☐ ______________________

Topsoil Pile Labeled ☐ ______________________

Storm water controls in place ☐ ______________________

Other: __________ ☐ ______________________

***Seed Mix*** **# PLS/ft2** __________

**Rate (#/acre)** __________

Based on pre-disturbance vegetation ☐ ______________________

Includes quick establishing native plants ☐ ______________________

Forbs and shrubs include ☐ ______________________

Herbicide application anticipated? ☐ ______________________

Seed tags gathered ☐ Source: ______________________

Seed rate apropriate based on PLS ☐ ______________________

Seed stored in appropriate conditions ☐ ______________________

Seed viability sample ☐ ______________________

Germ tested within last 365 days ☐ ______________________

Seeding Depth ☐ ______________________

Authorized changes from SWMP seed mix ☐ By: ______________________

Seeding rate doubled for broadcast seeding ☐ ______________________

Other: __________ ☐ ______________________

***Crimping***

Straw standing ☐ ______________________

No piles of straw mulch ☐ ______________________

Other: __________ ☐ ______________________

***Equipment***

Seeder calibrated ☐ By: ______________________

Seeder working properly ☐ ______________________

Depth bands ☐ ______________________

Amendment spreader calibrated ☐ Type: ______________________

Spreader working properly ☐ ______________________

Seed raked into soil if broadcast seeded ☐ ______________________

Other __________ ☐ ______________________

# CDOT Revegetation Checklist

## Checklist Page 2

| | | |
|---|---|---|
| **QC Items** | | **Comments** |
| **Compost** **Rate** ______ | | |
| STA Certified | ☐ | |
| Tilled into top 6 inches | ☐ | |
| Topsoil pile clearly marked | ☐ | |
| Changes in compost rates authorized | ☐ | By: |
| Other: ______ | ☐ | |
| ***Mulch*** **Specified Rate** ______ | | |
| Weed Free Certifications | ☐ | |
| Adequate length (6 inch min.) | ☐ | |
| Adequate coverage (60% coverage) | ☐ | |
| Tackifier added | ☐ | |
| Other: ______ | ☐ | |
| ***Imported Soil*** | | |
| Soil test obtained from native and imported soil | ☐ | |
| Soil test reviewed by CPSS | ☐ | CPSS: |
| Integrated Weed Management Plan Developed | ☐ | |
| Authorization to seed outside of seeding window | ☐ | By: |
| Other: ______ | ☐ | |
| ***Soil Preparation*** | | |
| Soil decompacted | ☐ | |
| Amendments tilled into soil surface | ☐ | |
| Seedbed prep, no large rocks or clods | ☐ | |
| ***Site Check-off*** | | |
| Noxious weeds present | ☐ | Y/N: By: |
| Spraying required | ☐ | Y/N: By: |
| Self sustaining vegetation | ☐ | Y/N: By: |
| 70% cover documented | ☐ | Y/N: By: |
| Interseeding required | ☐ | Y/N: By: |
| Erosional issues | ☐ | Y/N: By: |
| Maintenance punchlist completed | ☐ | Y/N: By: |
| Other: ______ | ☐ | |
| ***Permit Closeout*** | | |
| Continuing Erosional issues | ☐ | Type: |
| Vegetative cover adequate | ☐ | Percentage: Transects: |
| Landscape Architect reviewed/sign off | ☐ | By: |
| Date revegetation completed/sign off | ☐ | Date: |
| Stormwater permit deactivated | ☐ | Date: |
| Other ______ | ☐ | |

**Additional Notes or Comments**

______

______

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# Appendix L: Assessment of CDOT Revegetation Practices for Highway Construction Sites-Implementation Plan Framework

# Assessment of CDOT Revegetation Practices for Highway Construction Sites
# Implementation Plan Framework

Section 4 of Assessment of CDOT Revegetation Practices for Highway Construction Sites Report provides a list of revegetation conclusions and recommendations based on the ease of implementation, cost and time efficiency and environmental and compliance risk (See Table 4a). The implementation of these recommendations will provide a high probability that the overall CDOT revegetation process will improve, and meet the goals of this research study listed below.

- Provide a list of potential revegetation practices that CDOT can implement
- Categorize the potential changes based on risk and timeframe required to implement those changes.
- Identify and evaluate a series of revegetation practices for construction sites that will significantly reduce the revegetation time necessary to achieve Construction Stormwater Permit deactivation and sustainable site stabilization
- Evaluate revegetation practices that could reduce the amount of financial and professional resources needed for environmental compliance, monitoring and protection
- Identify revegetation practices that take into account and consider potential climate change conditions for sustainable site stabilization
- Identify and recommend revegetation practice improvements and enhancements that can be of immediate use within all CDOT regions

Table L-1 provides a framework for developing an implementation plan to execute many of the recommendation provided in Section 4. This implementation plan framework provides a step-wise approach toward developing an overall comprehensive implementation plan. The framework contains the following components:

- Sequence of Actions
- Action
- Responsible Party
- Date Initiated
- Expected Date Completed

It will not be possible to immediately implement all of the recommendations provided in Section 4 (Table 4.1). It will require a coordinated effort among numerous CDOT representatives and regions to identify the recommendations that address the most overall risk to CDOT. It will also require support from upper CDOT management; therefore, it is important to find and leverage off of a Program Champion. This Program Champion could be the Superintendent of Maintenance who may have a great interest in the costs associated with revegetation re-work.

This implementation plan should follow and Environmental Management System (EMS) approach using the Plan-Do-Check-Act methodology. Initially, this implementation plans should be reviewed and revised as needed by the CDOT Program Champion on a quarterly to every 6 months basis to assess program progress and success.

## Table L-1 Highway Construction Sites Implementation Plan Framework

| Sequence of Actions | Actions | Responsible Party | Date Initiated | Expected Date Completed |
|---|---|---|---|---|
| 1 | Find a champion that will oversee the progress of this Implementation Plan | EDU Manager | | |
| 2 | Establish a meeting with CDOT Maintenance Superintendent, RTDs and Program Engineers to resolve issue of competing interests | HRED Manager/ EDU Manager | | |
| 3 | Work with the CDOT Water Quality Advisory Committee in developing a Post Construction Program; revisit punchlist and maintenance role | HRED Manager | | |
| 4 | Develop a revegetation training program for CDOT and subcontractors on CDOT specifications and processes | HRED Manager | | |
| 5 | Develop new or revised specifications that identify revegetation responsibilities | EDU Manager | | |
| 6 | The Ecological Design Unit (EDU) develops a list of priority issues to implementation based on risk elements; develop performance metrics | EDU Manager | | |
| 7 | EDU develops and provides a presentation to upper CDOT Management on critical issues for revegetation success; gain support | EDU Manager | | |
| 8 | Develop a marketing plan or approach to sell high priority issues to regions and engineers | EDU Manager | | |
| 9 | Identify existing, new or hire revegetation specialists to directly monitor contractors at critical revegetation times. | HRED Manager/ EDU Manager | | |
| 10 | Coordinate with CDOT Water Quality Advisory Committee members or other representatives to revised SWMP requirements. Develop a template outline for required project specific landscape design plans | EDU Manager | | |
| 11 | Monitor performance metrics and evaluate success; use adaptive management approaches; coordinate with Champion | EDU Manager | | |