Report No. CDOT-2010-4
Final Report

INVESTIGATION OF RE-USE OPTIONS FOR USED TRACTION SAND

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June 2010

COLORADO DEPARTMENT OF TRANSPORTATION
DTD APPLIED RESEARCH AND INNOVATION BRANCH

Technical Report Documentation Page

1. Report No. CDOT-2010-4	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle INVESTIGATION OF RE-USE OPTIONS FOR USED TRACTION SAND		5. Report Date June 2010
		6. Performing Organization Code
7. Author(s) Alex K. Pulley and Kate Baird, PE		8. Performing Organization Report No.
9. Performing Organization Name and Address Felsburg Holt and Ullevig 6300 S. Syracuse Way Suite 600 Centennial, CO 80111		10. Work Unit No. (TRAIS) CDOT-2010-4
		11. Contract or Grant No. 40.11
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 Final. January 2008-June 2010
		14. Sponsoring Agency Code

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

16. Abstract

The Colorado Department of Transportation (CDOT) uses approximately 24,000 tons of traction sand annually, especially in mountain locations. Once traction sand is applied, street sweepers reclaim approximately 50% of the sand, which is either stockpiled at a maintenance facility or disposed of in a landfill. The remaining 50% is left on the roadway and can collect in water quality ponds and rivers due to precipitation events.

This research project consolidated physical and chemical characterization data on reclaimed traction sand from multiple mountainous areas in Colorado. The Principal Investigator determined that heavy metal contamination in the reclaimed sand is within naturally occurring levels and does not pose a risk to human health through the comparison to natural background and risk-based soil values. Additional volatile organic compounds and semi-volatile organic compound characterization sampling is required for the Colorado Department of Public Health and Environment (CDPHE) to approve beneficial re-uses.

A simple bench-scale composting test was conducted to determine if elevated petroleum levels could be reduced through natural bioremediation. These results indicated that the simple actions did not reduce the levels to below regulatory levels.

Implementation:

A market analysis and cost-benefit analysis demonstrated that an aggregate material that meets CDOT specifications could be prepared at a reasonable cost by combining the reclaimed materials with a coarse aggregate supplement. Prior to the use of any salvaged traction sand material, federal and state regulations require that the material be approved by the CDPHE.

17. Keywords sedimentation, reclaimed traction sand, recycling, heavy metal contamination, total petroleum hydrocarbons (TPH), oil and grease (O&G), cost-benefit analysis		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161; www.ntis.gov	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 93	22. Price

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

INVESTIGATION OF RE-USE OPTIONS FOR USED TRACTION SAND

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Sponsored by the
Colorado Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

June 2010

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ACKNOWLEDGEMENTS

Special thanks to the following CDOT Traction Sand Study Panel Members:

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EXECUTIVE SUMMARY

The Colorado Department of Transportation (CDOT) uses approximately 24,000 tons of traction sand annually, especially in mountain locations. Once traction sand is applied, street sweepers reclaim approximately 50% of the sand, which is either stockpiled at a maintenance facility or disposed of in a landfill. The remaining 50% is left on the roadway and can collect in water quality ponds and rivers due to precipitation events.

This research project consolidated physical and chemical characterization data on reclaimed traction sand from multiple mountainous areas in Colorado. The Principal Investigator determined that heavy metal contamination in the reclaimed sand is within naturally occurring levels and does not pose a risk to human health through the comparison to natural background and risk-based soil values. Additional volatile organic compounds and semi-volatile organic compound characterization sampling is required for the Colorado Department of Health and Environment (CDPHE) to approve beneficial re-uses.

A simple bench-scale composting test was conducted to determine if elevated petroleum levels could be reduced through natural bioremediation. These results indicated that the simple actions did not reduce the levels to below regulatory levels.

A market analysis and cost-benefit analysis demonstrated that by combining the reclaimed materials with a coarse aggregate supplement, an aggregate material that meets multiple CDOT specifications could be prepared at a cost that is generally below the cost of virgin materials.

Based upon the information presented in this document, the table below presents the recommended re-use options for reclaimed traction sand. These uses are selected based on the ability of the traction sand to be supplemented to meet CDOT's aggregate specifications and a positive cost/benefit analysis when compared to purchasing virgin materials.

Recommended Uses of Reclaimed Traction Sand

CDOT Aggregate Specification	Common Uses
ABC (Class 2)	Not commonly used, but would be road base
ABC (Class 3)	Not commonly used, but would be road base
ABC (Class 4)	Not commonly used, but would be road base
ABC (Class 5)	Road Base, tends to be used in Mountains
ABC (Class 6)	Road Base, extremely common on Front Range
ABC (Class 7)	Not commonly used, but would be road base
Bed Course Material	Pipe Bedding, structural backfill Class 1 can pass for this material
Grading SX Master Range	SX is a ½" maximum aggregate size asphalt mix, top lifts
Median Cover Aggregate	In concrete used to fill in raised islands
Structural Backfill (Class 1)	Bridge or Retaining Wall Select Backfill, Pipe Bedding and Backfill
Structural Backfill (Flow Fill Concrete)	Pipe or Inlet Backfill within Streets, Bridge Backfill

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LIST OF ACRONYMS

AASHTO	American Association of State Highway Transportation Officials
ABC	Aggregate Base Course
c/a	Coarse Aggregate
CDPHE	Colorado Department of Public Health and Environment
CDOT	Colorado Department of Transportation
CSEVs	Colorado Soil Evaluation Values
DOTs	Departments of Transportation
DTD	Division of Transportation Development
GIS	Geographic Information Systems
kg	kilograms
MgCl	Magnesium Chloride
mg	milligrams
mmohs	millimohs, scale of mineral hardness
mm	millimeter
um	micrometer
N/A	not applicable
NH3	Ammonia
O&G	Oil and grease
pH	potential Hydrogen
RCRA	Resource Conservation and Recovery Act
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TRPH	Total Recoverable Petroleum Hydrocarbons
USGS	United States Geological Survey

1.0 INTRODUCTION

1.1 Background

The Colorado Department of Transportation (CDOT) applies clean, sharp sand mixed with salt to roadway surfaces during snow conditions to improve vehicle traction and thus roadway performance and safety during inclement conditions. When springtime runoff washes these sands from the roadway, the sands and any other accumulated foreign matter, unless properly managed, are considered pollutants to waters of the state. CDOT has undertaken significant efforts such as street sweeping and using ponds and other controls to catch sand to control the release of traction sands before they enter waters of the state. However, accumulation of sands produces management difficulties and the potential exists for deleterious substances, namely total petroleum hydrocarbons (TPH) and oil and grease (O&G) in the reclaimed sands that could increase the cost of sand disposal. This document outlines a summary of a literature search, characterization of reclaimed traction sand, a testing methodology to assess if simple remedial actions taken by CDOT can reduce organic contaminants in reclaimed traction sand and enhance recycling potential, a market analysis, and recommendations for re-use.

1.2 Current Winter Maintenance Practices

CDOT's winter road maintenance program generally focuses on two types of roadway treatments, traction sand and the liquid anti-icing compound magnesium chloride (MgCl). The general trend in the metropolitan areas is to utilize MgCl as much as possible. The primary reason for this trend is because the use of MgCl reduces the particulate matter in the air that contributes to Denver's "Brown Cloud." Traction sand, as it is continually driven on will break down and the smaller, particulate matter is then released to the atmosphere, thus contributing to the "Brown Cloud." MgCl, because it is a liquid, does not have this type of effect. Additional reasons for using MgCl was that it was believed to reduce the impact to the roadside environment, specifically water resources (e.g., creeks, rivers, and wetlands). However, in recent years there has been concern regarding the environmental effects of MgCl, specifically to roadside vegetation. Additionally, MgCl has various limitations, such as very low temperatures and heavy snowfall.

Some areas of traction sand application will always be required because of the steepness of the roadway and the volume of snowfall, like on Vail Pass and Berthoud Pass. During the Market Analysis, these areas were considered as hot spots for the collection of used traction sand.

The traction sand that CDOT applies on its roads contains not only sand, but also a mixture of salt, which is a common practice among other municipal and state Department of Transportation (DOTs). The inclusion of salt in the mixture actually allows for the reduced amount of sand needed for traction. The salt lowers the freezing point of the surrounding water and keeps the sand from clumping so it will stick to the road better, thereby requiring less application of sand. Additionally, it keeps the sand from freezing, which allows for easier spreading on the roadways.

IceSlicer is often used instead of a salt/sand mixture, but requires training for proper application. The material is clear and the driver cannot tell if the deicer is being applied and therefore will increase the application rate until they can tell that the product is being applied. This results in over-application and will needlessly introduce materials onto the roadway and eventually the surrounding environment.

The amount of salt/sand or IceSlicer depends on the geographic location within the state. A summary of known application practices for various CDOT Regions is presented below.

Region 1

- Salt/sand mixture ranges from 5 to 18 percent salt
- In one year, picked up 13,000 tons of used traction sand on Berthoud Pass; 4,000 tons on Straight Creek; and 7,200 tons on West Vail Pass
- Approximately 20,000 tons of salt/sand mixture was applied on West Vail Pass, with about 40 percent picked up

Region 2

- Picks up the traction sand and uses it for shouldering
- General approach is to reduce the usage of sand and rely on liquid deicers as much as possible. This is a feasible situation for this Region because of the lack of heavily traveled mountain passes.
- Salt/sand mixture ranges from 5 to 20 percent salt

Region 3

- CDOT is required to sweep used traction sand within 48 hours of the storm event in metropolitan areas
- Mixes used sand back into the new sand, which requires some screening for trash and debris
- Salt/sand mixture is approximately 10 percent salt

Region 4

- Salt/sand mixture is approximately 15-20 percent salt.
- The City of Fort Collins is currently using liquid deicer (APEX-a non-magnesium chloride cold temperature liquid) in addition to IceSlicer
- This Region does not have a heavily traveled mountainous pass

Region 5

- Data from Region 5 was not available at the time of data compilation

Region 6

- Only consistently uses sand/salt mixture in two areas (I-70 from Wadsworth to Morrison Road) and US 93 because of the steep roadway and wind, respectively
- Many of the surrounding communities still use traction sand and the sand gets tracked onto CDOT roads, which then have to be swept
- Applies approximately 500 tons of salt/sand mixture in a single year
- Approximately 50 percent of applied salt/sand mixture is picked up
- Salt/sand mixture is approximately 30 percent salt

1.3 Problem Statement

The use of traction sand has created problems with sedimentation in receiving streams, particularly in mountain streams. As a result, the Colorado Department of Public Health and Environment (CDPHE) has classified some streams as “impaired” because of high sedimentation. Over the past 10 or more years, CDOT has implemented numerous mechanisms attempting to contain the traction sand before it is released to streams. As part of sediment control in these watersheds and other locations, CDOT collected more than 100,000 tons of used sand during the 2004-2005 winter seasons. The cost of disposing of this traction sand is high and expected to increase substantially as landfill space becomes limited.

Since the cost of using these traditional resources is rising, re-use of materials is becoming a more attractive option for CDOT highway applications. Re-use of traction sand for other highway applications is an untried concept to many CDOT staff because they do not have accurate, current, and accessible information to help them evaluate possible uses on their projects. In addition, CDOT specifications are perceived to imply not only a preference, but a requirement for freshly quarried materials.

1.4 Objectives of Study

The focus of the research project was to identify a viable alternative(s) for the use of used traction sand to minimize landfill disposal in a cost-effective manner.

The objective of this project was to perform and document the research to determine alternate uses for the re-use of traction sand. The report is divided into four main sections that summarize these objectives:

- Literature Review
- Characterization
- Small-Scale Bench Testing
- Market Analysis
- Recommendations

2.0 LITERATURE SEARCH

This section presents the results of a literature search that was performed in order to determine possible uses for traction sand. Felsburg Holt & Ullevig (the Principal Investigator) conducted an internet search for documented traction sand re-use options. A targeted phone interview process was conducted for various DOTs in states with significant snowfall and municipalities with large snowfalls or known traction sand recycling programs. A summary of the states and municipalities included in the search are presented along with a summary of the results.

2.1 Information Sources

As previously mentioned, an internet search was conducted to determine documented traction sand re-use programs. Utilizing the information collected from the internet search, the telephone interviews were focused on DOTs and municipalities that may have information that could be useful to this research. Generally, there was very limited information on currently implemented traction sand re-use programs, so the vast majority of the contacted DOTs and municipalities were intuitively determined based upon states with large mountains, large amounts of snow, similar road conditions, or local municipalities. The City of Edmonton was contacted because it has a known traction sand re-use program.

Below is a list of the States/municipalities that were contacted during the interview process. The results of the interview portion of the literature search is presented in the following section.

- Montana DOT
- Caltrans (California DOT)
- Alaska DOT
- Idaho DOT
- Minnesota DOT
- New York DOT
- Oregon DOT
- Utah DOT
- Vermont DOT
- Washington DOT
- City of Fort Collins
- City of Greeley
- City of Reno
- City of Lake Tahoe
- City of Edmonton

2.2 Results

This section presents the results of the interviews conducted with state DOTs and municipalities. Generally, there were no active traction sand re-use programs in place at the agencies contacted. Many stated that cost of preparing the materials for re-use were prohibitively expensive. Table 2-1 presents a summary of the entities that have existing re-use programs. A summary of the interviews, including all contacted, even if they did not have an existing program, is presented in Appendix A.

Table 2-1 Summary of Existing Traction Sand Re-use Programs

Entity	Re-use Program Notes	Advantages	Disadvantages
Montana DOT	Mixed with seed for vegetative cover in the highway median. Re-use is on a small scale, a percentage of the recycled sand is mixed with new material every year prior to application.	Eliminates noxious weed growth	Costly ($50 per ton)
City of Edmonton, Alberta	Large Scale Re-use program since 1980s	Lessens amount going to the dump	Costly ($50 per ton)
California DOT	Sand is sent to a pick up location and placed in stockpiles in preparation for aggregate company to pick up and re-use in their operations.	Inexpensive way to dispose of material for the agency	None

See Appendix A for complete list of contacted agencies and their responses

3.0 MATERIAL CHARACTERIZATION

This section summarizes the sampling methods and subsequent results of traction sand sampling efforts conducted by CDOT and the Principal Investigator. Reclaimed traction sand was evaluated to determine the chemical and physical characterization of the material. This section also provides a comparison of the results to Colorado background soil concentrations, risk-based screening levels,and CDOT Specifications. In Colorado, the CDPHE developed Colorado Soil Evaluation Values (CSEVs) as risk-based screening levels for soil.

3.1 Methods

Traction sand was collected from a number of different sources and locations in an effort to determine if differences exist between collection areas. CDOT and/or the Principal Investigator collected sand from the roadside, basins, and a berm used to store sand and other materials. CDOT and/or the Principal Investigator also sampled sites on Berthoud Pass (US40), Eisenhower Tunnel (I-70), and Vail Pass (I-70). These sites represent the primary source of traction sand material in north-central Colorado because the mountain passes are the locations with the largest amount of sand usage and are the areas where sand usage will continue. Sampling was conducted in 2002, 2003, 2004, and 2007 (Clear Creek, 2008).

To obtain a representative sample of the range of conditions found in the mountain passes, composite samples were collected. The method to collect the composite samples was ensured consistency in collection methods between sampling events. The sampling protocol is presented in **Appendix B**.

The samples were taken to contract laboratories to analyze the samples for soil pH, percent solids, specific conductivity, total organic compounds (TOC), O&G, TPH, Resource Conservation and Recovery Act (RCRA) metals (total), copper (total), zinc (total), phosphorus (total and dissolved), nitate+nitrite, ammonia, nitrogen (total and dissolved), and two sieve tests (2000 micrometers (um) and 22,400 um). The results of the chemical analysis are presented in **Section 3.2**.

Samples were also subjected to a sieve analysis to determine the size of the resulting traction sand. Ten different sieve sizes were used from 0.75 inch to 0.0029 inch (No. 200). The results of the sieve analysis are presented in **Section 3.3**. The sieve analysis is important to consider because it is the primary factor for determining the appropriate usage of aggregate material in CDOT operations.

3.2 Chemical Characteristics

Table 3-1 presents the results of the Traction Sand sampling analysis. The table includes the data separated by source (i.e., roadside and basins). The number of roadside samples ranged from 4 to 19 samples per analyte and the basins had 4 to 5 samples, per analyte. To demonstrate the distribution of the individual data, box and whisker plots for each analyte are presented in **Figure 3-1**.

It should be noted that some of the data included in this analysis was collected from 2002-2007 for a separate research endeavor in CDOT Region 1. The results of that study are presented in the document “Characterization of Used Traction Sands: 2008 Report” (Clear Creek, 2008) (**Appendix C**).

A sample of a berm that was partially constructed with reclaimed traction sand had also been collected by CDOT Region 1. Through discussion with CDOT staff, the berm sample may not be representative of traction sand. The berm site used to store the traction sand material was also used by the Town of Vail for the disposal of various materials excavated during the construction of a Public Works facility. Because the berm contained a mixture of disposal materials and to avoid the mischaracterization of traction sand, the berm sample was removed from further analysis.

Table 3-1 Summary Statistics of Traction Sand Analytical Results by Material Source

(mg/kg, unless otherwise noted)

	Roadway (I-70, US40; 2002, 2003, 2004, 2007)					**Basins (I-70 Tunnel, US40, VP; 2004, 2007)**				
	# of Samples	**Detection %**	**Minimum**	**Maximum**	**Mean**	**# of Samples**	**Detection %**	**Minimum**	**Maximum**	**Mean**
Arsenic	27	74%	1.0	4.1	1.8	7	100%	1.5	3.2	2.2
Barium	27	100%	20.2	195	58.9	7	100%	32.5	76.4	54.6
Cadmium	27	0%	nd	nd	NA	7	0%	nd	nd	NA
Chromium, total	27	100%	4.5	23.5	12.5	7	100%	9	20	12.6
Copper	27	100%	2.1	21	11.7	7	100%	9	23	15.4
Lead	27	100%	3.4	18.5	10.8	7	100%	7.48	26.8	13.2
Mercury, Total	27	0%	nd	nd	NA	7	14%	0.19	0.19	NA
Selenium	27	26%	0.16	1.3	0.9	7	100%	0.12	0.5	0.3
Silver	27	0%	nd	nd	NA	7	0%	nd	nd	NA
Zinc	27	100%	12.4	104	55.9	7	100%	49	105	67.7
TPH	4	100%	78	170	122.3	5	100%	31	80	57.6
O&G	27	93%	500	6,200	1,959	7	100%	550	1,700	1,211
Phosphorus, total	14	50%	8.6	103	63.4	5	100%	36	136	81.8
Phosphorus, dissolved	8	100%	0.0072	0.077	0.042	NA	NA	NA	NA	NA
Dissolved Ammonia (NH^3)	8	63%	0.01	0.62	0.193	NA	NA	NA	NA	NA
Dissolved Nitrate+Nitrite	8	100%	0.02	0.342	0.125	NA	NA	NA	NA	NA
Dissolved Inorg. Nitrogen	7	100%	0.03	0.462	0.165	NA	NA	NA	NA	NA
Total Dissolved Nitrogen	4	100%	0.26	0.28	0.275	NA	NA	NA	NA	NA
pH	5	100%	7.4	8.2	7.8	5	100%	7.5	7.9	7.72
TOC %	15	100%	0.5	2.4	1.07	5	100%	0.6	0.8	0.68
Specific Cond. (mmhos/cm)	19	100%	0.01	14.4	1.58	5	100%	0.298	6.73	3.34
Pyrene (ug/kg)	0	NA	0	0	NA	0	NA	0	0	NA
Sieve, 2000 um (% passing)	5	100%	42.3	70	63.3	5	100%	66.5	74.5	NA
Sieve, 22400 um (% passing)	5	100%	100	100	100	5	100%	100	100	NA

nd = Analyzed, but not detected
NA = Analysis not conducted
mg/kg = milligrams per kilogram
mmhos/cm = millimohs per centimeter
ug = microgram
ug/kg = micrograms per kilogram
VP = Vail Pass

Figure 3-1 Box and Whisker Plots of Individual and Combined Traction Sand Data (Concentration reported in parts per million)

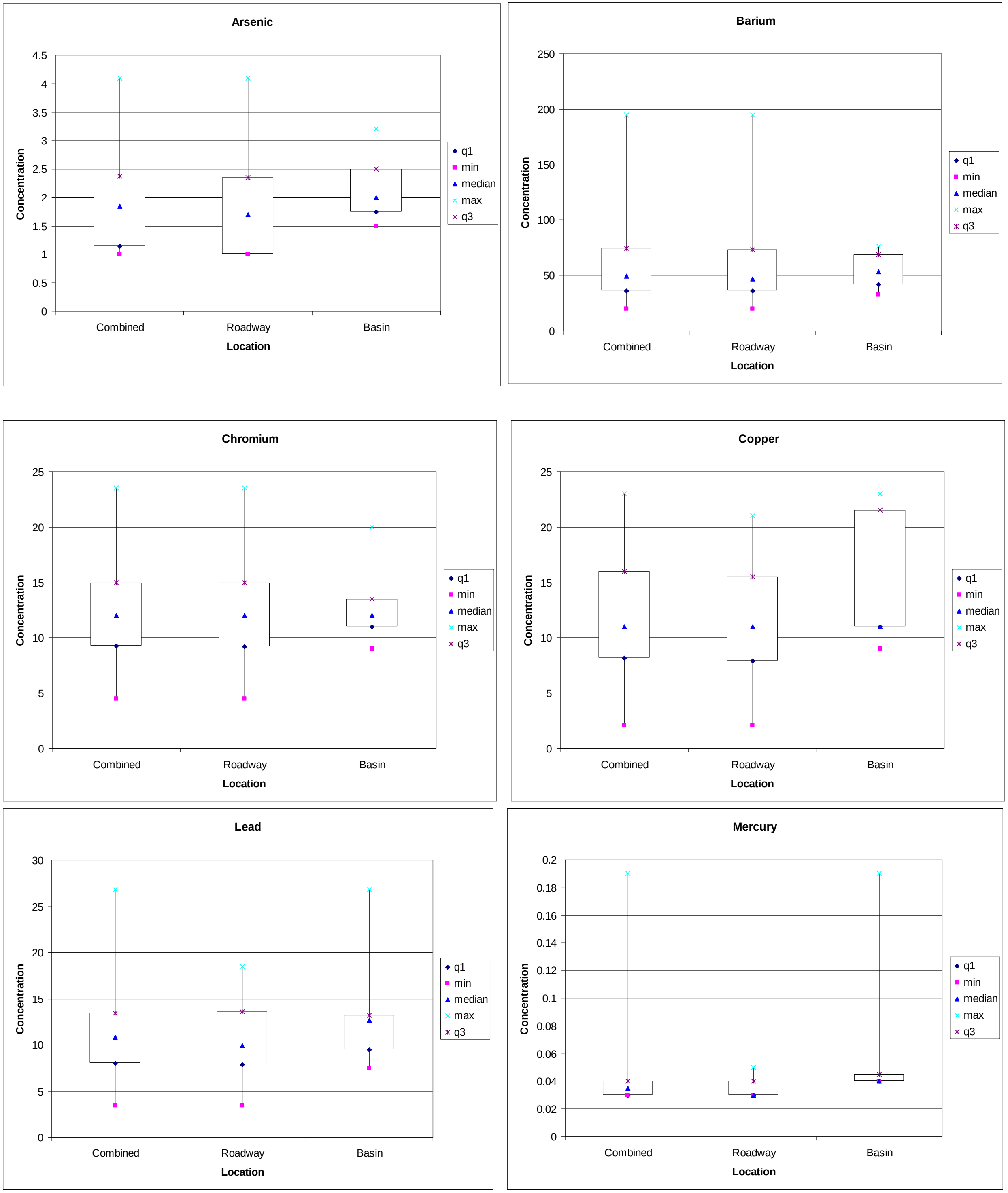
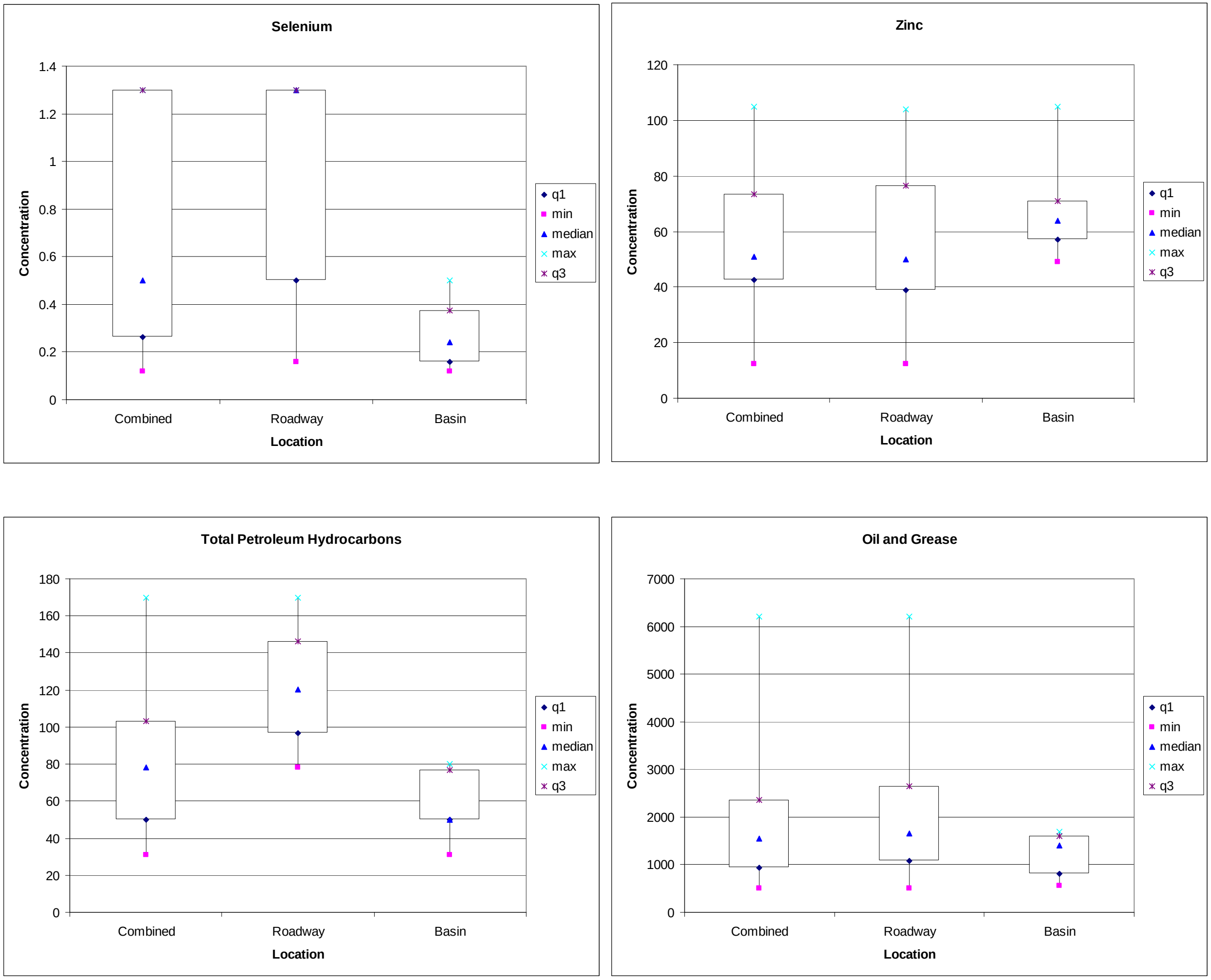


Figure 3-1 Box and Whisker Plots of Individual and Combined Traction Sand Data (Concentration reported in parts per million) *(continued)*



Generally, the data from the roadside and basins are similar for metals, pH, TOC, and the sieve tests. The difference between sample results from the roadway and basin samples does not appear to be substantial. Based on the collected data, outside influences on metal chemistry do not appear to affect one source more than another and therefore these data are sufficiently similar to consider them in one dataset. Table 3-2 presents the metal concentrations data combined into one data set.

Conversely, the data for TPH, O&G, and specific conductance between the two sources are sufficiently different to consider them separately. The concentrations of TPH and O&G were higher in the roadside and then decrease dramatically in the basin samples. The TPH minimum, maximum, and mean concentrations in the basins are more than half of the concentrations in the roadside. Similarly, the O&G maximum and mean concentrations in the basins were nearly an order of magnitude less than the roadside. The likely reason for this observation is that the petroleum products are being diluted through runoff or being broken down through natural bacterial action.

Table 3-2 Summary Statistics for Combined Traction Sand Data (mg/kg)

	Number of Samples	Detection Frequency	Minimum	Maximum	Mean	Standard Deviation
Arsenic	34	79%	1.0	4.1	1.93	0.77
Barium	34	100%	20.2	195	58.0	33.6
Cadmium	34	0%	nd	nd	NA	NA
Chromium, total	34	100%	4.5	23.5	12.6	4.96
Copper	34	100%	2.1	23	12.5	5.31
Lead	34	100%	3.4	26.8	11.3	4.39
Mercury, total	34	3%	0.19	0.19	0.19	NA
Selenium	34	42%	0.12	1.3	0.79	0.50
Silver	34	0%	nd	nd	NA	NA
Zinc	34	100%	12.4	105	58.4	23.6
TPH	9	42%	31	170	86.3	44.5
O&G	34	97%	500	6,200	1,805	1,150

NA = not applicable
nd = not detected
mg/kg = milligrams per kilogram

3.3 Traction Sand Comparison

When analyzing environmental media for potential contamination, in this case soil, it is imperative to compare analytical results to background concentrations and risk-based screening levels to determine if potential contamination exists and whether or not concentrations pose a potential risk to human health, respectively. The following sections discuss comparing the CDOT traction sand analysis previously described to these benchmarks. Table 3-3 presents the combined analytical traction sand data comparison to Colorado background concentrations and risk-based concentrations.

3.3.1 Background Levels

It is important to consider background levels when looking at environmental media with potential heavy metal contamination. Background data are levels of metals that naturally occur in the environmental media, in this case soil.

The U.S. Geological Survey (USGS) generated the earliest database of background soil levels for the U.S. in the mid-1960s and completed in the late 1970s. This data set commonly is referred to as the “Shacklette data” because the effort was conceived and coordinated by H.T. Shacklette. This data from Boerngen and Shacklette (1981) was queried using Geographic Information Systems (GIS) to obtain only the results from Colorado. Studies by the USGS in the past few years have been conducted and were also used for this analysis. The purpose of the USGS 2005 study was to provide estimates of the range of element abundance in soils that generally were unaffected by human activities (Smith et al., 2005). Again, Colorado specific data was sorted and used for comparison to CDOT traction sand analytical results.

These data from Boerngen and Shacklette (1981) and Smith et al., (2005) were combined to create a larger, more comprehensive dataset for comparison. As shown in Table 3-3, all of the mean metal concentrations in the traction sand samples were less than the mean background concentrations from this combined data set. Furthermore, the maximum detected metal concentrations in the traction sand samples were less than the mean background concentrations, with the exception of zinc. The maximum detection of zinc in the traction sand is only slightly greater than the mean background, but more than an order of magnitude less than the maximum background detection for zinc.

This demonstrates that the concentrations of heavy metals detected in the reclaimed CDOT traction sand are within, and less than, naturally occurring soil levels. This supports the conclusion that the no heavy metal contamination exists in the traction sand beyond what naturally occurs.

TPH and O&G are not naturally occurring materials and therefore, do not have corresponding background concentration levels. These materials are anthropogenic and are introduced into the traction sand through normal operations of a highway facility. They enter the system through vehicle leaks and during automobile accidents.

3.3.2 Colorado Soil Evaluation Values

Comparing concentrations of constituents detected in environmental media to risk-based screening levels is an important step in determining if traction sand may be deleterious to human health. Risk-based screening levels are developed by defining an exposure scenario and determining a concentration that is equivalent to an acceptable level of risk. Typically, the most conservative (or protective) exposure scenario is for a residential receptor. CDPHE has developed risk-based screening levels for soil, which are called CSEVs (CDPHE, 2007).

Table 3-3 shows the detected concentrations of the traction sand compared to the calculated CSEVs. Residential values are shown because they are more conservative than Industrial values. The endpoint for all the metals, except for chromium, is for non-carcinogenic endpoints. Non-carcinogenic endpoints are adverse health effects that could occur with sufficient exposure to a contaminant; for example, decrease liver functioning, eye irritants, skin rashes, etc. The endpoint for chromium is based on an increased rate of developing cancer. The chromium value was calculated using the hexavalent chromium, which is considerably more toxic than the more ubiquitous trivalent chromium. A list of all CSEV's, including industrial values, is presented in Appendix D.

Every metal, except for arsenic, is well below the CDPHE screening levels. This means that even at the maximum detected concentrations, no adverse effects are anticipated under typical exposure scenarios. Trivalent chromium naturally occurs at much higher concentrations than hexavalent chromium. The traction sand data does not differentiate between the valent states of chromium. If one makes the extremely conservative assumption that all of the detected chromium is the more toxic hexavalent chromium, the maximum detected concentration in the traction sand is also less than the screening level.

Even though the arsenic mean and maximum values are greater than the screening level, they are far below background concentrations. This is a common situation in Colorado and the western U.S. because natural arsenic concentrations in soil can be naturally elevated. As previously mentioned, because the arsenic data are well below the background concentrations, this indicates it is unlikely that contamination is present. Furthermore, the mean background concentration in soil is much greater than the CSEV.

The State of Colorado has not developed risk-based values for TPH or O&G. However, CDPHE has determined that soil with a TPH level of less than 500 parts per million and below CSEVs is considered solid waste (CDPHE, 2003). Because the traction sand is being re-used, it is not considered a waste material; therefore, this value may not be a target concentration. On-going discussions with CDPHE will attempt to identify the appropriate target concentration for re-use.

Table 3-3 Comparison of Combined CDOT Traction Sand to Background and Risk-based Concentrations

	Combined CDOT Traction Sand Data			**Colorado Background Values** [1] *(Statewide mean)*			**Colorado Soil Evaluation Values (CSEV) – December 2007**[2] (mg/kg)			**Is CDOT Mean > Background?**	**Is CDOT Mean > CSEV?**
	Mean (mg/kg)	*Max (mg/kg)*	*n*	*Mean (mg/kg)*	*Max (mg/kg)*	*n*					
Arsenic	1.89	4.1	34	237	1,150	125	0.39	Residential	carcinogenic endpoint	No	***Yes***
Barium	58.0	180	34	475	2,000	139	15,000	Residential	non-carc endpoint	No	No
Cadmium	0.54	1	34	41.4	120	65	70	Residential	non-carc endpoint	No	NA
Chromium, total	12.6	23.5	34	28.2	100	139	23	Residential	carcinogenic endpoint- Hex Cr	No	No
Copper	12.5	23.0	34	19.2	70.0	139	3,100	Residential	non-carc endpoint	No	No
Lead	11.3	26.8	34	44.8	126	136	400	Residential	non-carc endpoint	No	No
Mercury, Total	0.04	0.19	34	2.28	8.36	113	23	Residential	non-carc endpoint	No	No
Selenium	0.79	1.3	34	1.11	7.09	109	390	Residential	non-carc endpoint	No	No
Silver	0.96	1	34	5.77	13.0	43	390	Residential	non-carc endpoint	No	No
Zinc	58.4	105	34	89.4	2,080	104	23,000	Residential	non-carc endpoint	No	No

1 Combined Colorado soil background concentrations are from both Boerngen and Shacklette (1981) and Smith et al., (2005) for mountainous areas.

2 CSEVs for Industrial receptors and other analytes are presented in Appendix D.

mg/kg = milligram per kilogram

n = number of samples

3.3.3 TRPH Evaluation of Split Fractions of Reclaimed Traction Sand

One of the conclusions of “Characterization of Used Traction Sands: 2008 Report” (Clear Creek, 2008) was that the petroleum products (TPH) would be based in the smaller fraction (less than 0.85 millimeters [mm]) of the reclaimed sand. The current standard for traction sand is greater than 0.85 mm. Based on that theory, existing samples of reclaimed traction sand were sieved into two fractions: 1) material greater than 0.85 mm and 2) material less than 0.85 mm and each were analyzed for total recoverable petroleum hydrocarbons (TRPH). The TRPH methodology (EPA method 418.1) captures the entire range of TPH and O&G. However, the method does not distinguish between TPH and O&G. This method was chosen on the basis of understanding effect of the test on the entire range of petroleum hydrocarbons in a cost effective manner. Two—more expensive—sampling methods are required to distinguish between TPH and O&G.

The results of this evaluation are presented numerically in Table 3-4 and graphically in Figure 3-2. Figure 3-3 shows photographs of the three different fractions of the reclaimed material: pre-sieved, less than 0.85 mm, and greater than 0.85 mm.

Table 3-4 TRPH Sample Data for Spilt Fractions of Traction Sand Data

Location Type	Sample Description	TRPH Result	Units
Basin	Initial (Pre-Sieved)	450	mg/kg
	<0.85 mm Fraction	730	mg/kg
	>0.85 mm Fraction	660	mg/kg
Roadway	Initial (Pre-Sieved)	1700	mg/kg
	<0.85 mm Fraction	2200	mg/kg
	>0.85 mm Fraction	1100	mg/kg

mg/kg = milligram per kilogram

Figure 3-2 Graph of Spilt Fractions of Traction Sand TRPH Data

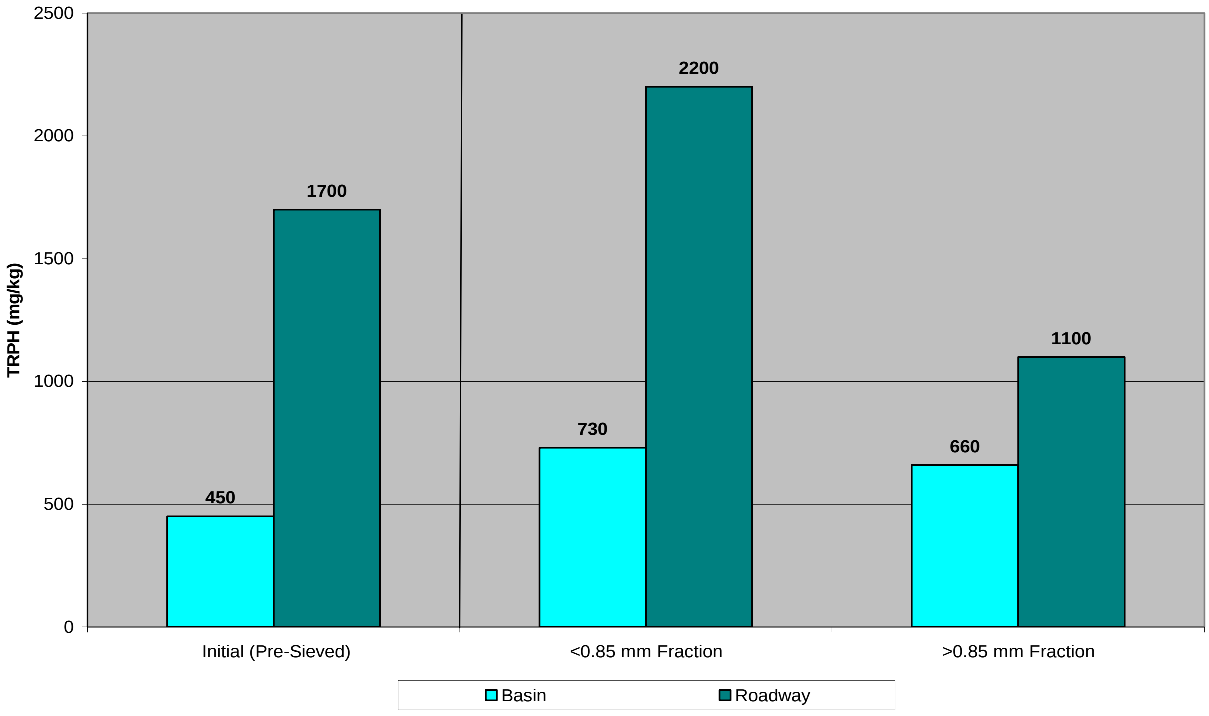


Figure 3-3 Photographs of Reclaimed Traction Sand Fractions

A physical gradation test was performed for the above samples. To generally understand the volume of material acceptable for use as traction sand (i.e., material greater than 0.85 mm), Table 3-5 presents the results of sieve analysis for the roadway and basin samples. The table demonstrates that there is more material that can be retained as usable traction sand from the Basins. This is because a smaller volume of material is passed through (or smaller than) the 0.85 sieve.

Table 3-5 Split Fraction of Traction Sand Sieve Analysis

	Percent Passing	
Sieve Size	Roadway	Basin
0.85 mm (#20)	52.2	39.5

The results of the splitting of the used traction sand in to the fractions greater than and less than 0.85 mm show two results, 1) the Roadway sample has higher levels of TRPH than the Basin and 2) the finer fraction (less than 0.85 mm) has higher levels of TRPH. The fact that the Roadway sample has a higher level of TRPH is consistent with the concept that there is a gradation of concentration as the material moves further from the roadway. While the smaller fraction does have greater TRPH concentrations, the larger fraction still has TRPH levels greater than regulatory levels (200 mg/kg).

It should be noted that there is inherent sample error in sampling the material that can affect the quantitative results. For example, both split fractions have higher concentrations of TRPH than the initial sample. The reason for this is likely because of the ‘nugget’ effect of the reclaimed material. This effect is the result of having pieces of asphalt in the sample itself, which can result in a high TRPH concentration in the results. Additionally, the reclaimed material is not consistent material because of the many items that can accumulate on the side of a roadway and in a detention basin (pieces pavement, vehicle parts, etc.).

3.4 Physical Characteristics

In order to determine the physical characteristics, i.e., particle size of the traction sand samples, the samples are measured by a sieve analysis. A given quantity of the samples are shaken through different sieves with standardized mesh openings. The mesh number is approximately the number of openings per lineal inch.

The results of the sieve analysis are presented in Table 3-6 below. Some sieve sizes are noted by a standard designation, i.e. No. 4. No. 4 sieve has openings of 0.187 inches. Larger standard sieve numbers (i.e., No. 200) have smaller openings.

Based on the sieve analysis, the sampled traction sand was found to be applicable for re-use by CDOT for multiple uses. Below is a description of the possible uses for traction sand as defined by the CDOT Standard Specifications for Road and Bridge Construction:

- Aggregate Base Course (ABC) - Class 2 and 3: ABC is placed on top of undisturbed soil and compacted prior to asphalt paving.
- Structure Backfill Material –Class 1: Structural Backfill is used as a foundation for structures such as retaining walls, box culverts and foundations.

The sieve analysis also indicated that the re-used traction sand could be used in a few other applications if the standard specifications were modified on a project specific basis. A summary of the specification analysis is included in Appendix E. Re-use applications are discussed further in Section 5, Market Analysis.

Table 3-6 Physical Characteristics of Used Traction Sand

Location	Percent Passing Sieve Size (%)									
	3/4”	1/2”	3/8“	No. 4	No. 10	No. 16	No. 40	No. 50	No. 100	No. 200
Vail Pass Roadside Mix	100	100	98	91	74	56	37	21	10	5
Berthoud Pass	100	100	100	94	69	43	35	13	6	2.7
Vail Pass Roadside	100	99	98	86	44	27	15	8	4	3.8
Vail Pass WQ Basin	100	100	100	96	69	51	36	26	19	17
I-70, Frisco to Copper Mntn	100	N/A	94.6	84.1	62.4	N/A	28.1	N/A	12.9	8.9
I-70, East Eisenhower	100	N/A	98.8	87.5	58.3	N/A	25.4	N/A	12.4	9.2
US 40, Empire-Berthoud Falls	100	N/A	97.3	85.8	41.2	N/A	10.9	N/A	5.4	4.1
US 40, Berthoud Pass East	100	N/A	98.6	86.4	45.4	N/A	16.8	N/A	8.5	6.2
US 40, Berthoud Pass West	100	N/A	99.4	79.7	32.3	N/A	8.8	N/A	4.5	3.1
SH9, Hoosier Pass North	100	N/A	99.5	83.7	54.9	N/A	21.2	N/A	11.4	7.8
I-70, Copper Mt. to Vail Pass	100	N/A	98.4	89.1	70.6	N/A	33.1	N/A	15.9	10.9
I-70, Vail Pass to E. Vail	100	N/A	99.5	88.5	66.2	N/A	29	N/A	13.1	8.4
Vail Sand Berm, S. side	100	N/A	100	93.2	72.4	N/A	33.5	N/A	15.4	10.2
I-70, Eisenhower T. East	100	N/A	83.9	76.8	66.2	N/A	47.3	N/A	33.7	27.3
I-70, Eisenhower T. West	100	N/A	99.1	89.8	70.9	N/A	32.4	N/A	15.1	10
US 40, Berthoud Pass East	100	N/A	99.6	89.2	65.1	N/A	25.6	N/A	10.4	6.7
US 40, Berthoud Pass West	100	N/A	99.3	88.4	59.5	N/A	25.8	N/A	13.1	9.2
I-70, Vail Pass to E.Vail	100	N/A	100	92.3	72.2	N/A	30.4	N/A	13.5	9.2
I-70, Vail Pass to Officers Gulch	100	N/A	100	94.5	74.1	N/A	34.2	N/A	15	9.5
I-70, Eisenhower Tunnel West	100	N/A	95.3	89.7	74.4	N/A	33.9	N/A	14.9	10
I-70, Silver Plume to Empire	100	N/A	96.6	89.4	65.2	N/A	29.1	N/A	13.9	9.8
US 40, Empire to Berthoud Falls	100	N/A	96.9	83.6	57.7	N/A	17.6	N/A	9.1	6.1
SH9, Alma to Hoosier Pass	100	N/A	93.2	73.7	48.9	N/A	17.6	N/A	9.3	7.2
Composite of CDOT Samples	100	N/A	99	92	76	N/A	35	N/A	0	9
R1 Environmental – Road	100	98.4	97.9	89.5	73.3	61.5	36.3	27.9	16.4	10.4
R1 Environmental - Basin	99.5	97.4	95.7	87.5	65.1	49.6	23.9	17.2	9	4.9
Standard Deviation (SD)	0.10	1.03	3.35	5.25	11.77	12.03	8.89	7.65	6.29	4.87
Mean	99.98	99.13	97.64	87.75	62.63	48.02	27.43	18.85	11.98	8.72
Mean plus 1 SD	100.08	100.21	100.99	92.99	74.39	60.05	36.32	26.50	18.28	13.58
Mean minus 1 SD	99.88	98.06	94.29	82.50	50.86	35.98	18.54	11.20	5.69	3.85

N/A = Not Available

4.0 SMALL-SCALE COMPOST TESTING

A bench scale test on reclaimed traction sand was performed to determine if short-term aging and/or limited environmental manipulation could reduce the potential for elevated petroleum hydrocarbons and oil and grease (O&G) values in stockpiled reclaimed sand. Based upon previous sampling activities and comparisons to background or naturally occurring soil conditions, the primary contaminants of concern in reclaimed traction sand in mountain areas are petroleum hydrocarbons and O&G. This conclusion is based upon a comparison of chemical characteristics of collected reclaimed traction sand samples found in different roadway locations to that of Colorado soils. The focus of this study design was to mimic a storage scenario and possible simple actions that could reasonably be undertaken by maintenance personnel to reduce the levels of petroleum hydrocarbons and O&G in reclaimed traction sand. A total of four test chambers were utilized to assess different treatment approaches. Photographs of the testing set up and at various times throughout the process are presented in Appendix F.

4.1 Materials

- 4—31 gallon tubs (16.7” x 32” 20.1”); Equivalent to 4.14 cubic feet
- 16.6 cubic feet of reclaimed traction sand
- Stainless steel sampling trowel
- Soil moisture and temperature probes
- Rain gauge
- Distilled water (chlorine in tap water may confound the test)
- Compost material

4.2 Methods

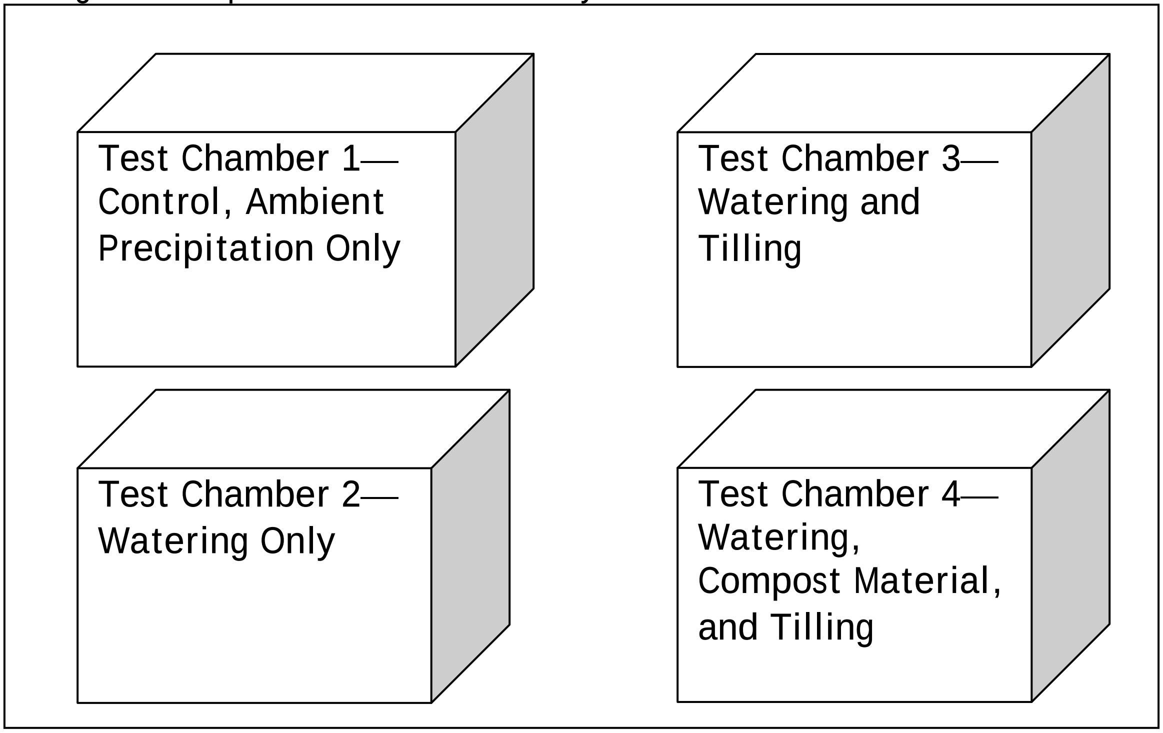
The goal of this test was to determine if a simple method exists to reduce or remove the petroleum hydrocarbons and O&G levels in reclaimed traction sand. This design was intended to reasonably mimic a CDOT maintenance yard setting. The following description includes the physical setup, sampling, ongoing activities, the location and source of the material, and the duration of the test.

4.3 Physical Setup

Four identical 31-gallon tubs (test chambers) were utilized for this test. Each tub was filled with reclaimed traction sand collected from stockpiles of commingled roadside sweepings on Vail Pass. Soil compaction was avoided. These test chambers were left exposed to the elements. Various remedial actions were tested including aging; moisture maintenance; moisture and tilling; and moisture, tilling, and the addition of a composting material. All of these remedial approaches were considered relatively simple measures that could be undertaken at any CDOT regional storage yard. The concept was to identify if minimal remedial actions can cause a substantial reduction in petroleum hydrocarbons and O&G soil values when compared with pre-test soil values. The assumption was made that the minimal actions would be the most cost-effective and implementable measures for maintenance facilities; so it was outside the scope of the test to perform more exhaustive remedial actions to reduce organic contaminants.

Figure 4-1 shows the physical layout of the proposed experiment, and is described below.

Figure 4-1 Experimental Test Chamber Layout



<u>Test Chamber 1</u>
Test Chamber 1 acted as the control test chamber and held a sand sample to determine if mere aging of the soil is a suitable remedial approach. This approach represents the condition of stockpiling reclaimed sands at maintenance yards.

<u>Test Chamber 2</u>
Test Chamber 2 was watered with enough water to moisten the material, but not enough to create runoff or fully saturated conditions. The goal of watering was to keep the percent moisture around 20 percent. The soil moisture was checked frequently to assure the soil did not dry out. The volume of distilled water added was noted at each watering. The goal of watering was to determine if providing additional moisture alone will enhance the microbial degradation process. The tubs were suitable as test chambers because small holes were placed in the bottom which allowed for sufficient drainage to limit or eliminate periods of saturated conditions. This reflects the conditions found in a reclaimed sand stockpile that is located within secondary containment. This test chamber was not mixed.

<u>Test Chamber 3</u>
Test Chamber 3 received the same watering scheme as Test Chamber 2, with the addition of mixing the material. The mixing of the material occurred approximately once a week.

<u>Test Chamber 4</u>
Test Chamber 4 received the same watering scheme as Test Chamber 2, but had two additions: compost supplement and the material was periodically deep-tilled. The compost material was BioComp®, a product developed by A1 Organics. This material consists of excrement from various feedstocks, brewers yeast, and several wood wastes, and biosolids. It has approximately 100,000 bacteria per gram of material. Appendix G presents the analytical results of testing of materials. Based on recommendations from A1 Organics, 20 pounds of BioComp® was added to the 31-gallon tub. The tilling took place during the same time as the watering, which occurred approximately once a week. The tilling action of the test material was

intended to more evenly distribute contaminants and microbes, potentially enhancing the remedial process. These actions were considered implementable at the maintenance facilities with limited effort and existing equipment.

4.4 *Sampling and Analysis*

Two types of samples were taken during this test; initial material characterization and test chamber sampling. The first established the baseline chemical conditions of the material and the latter assessed the chemical change throughout the test.

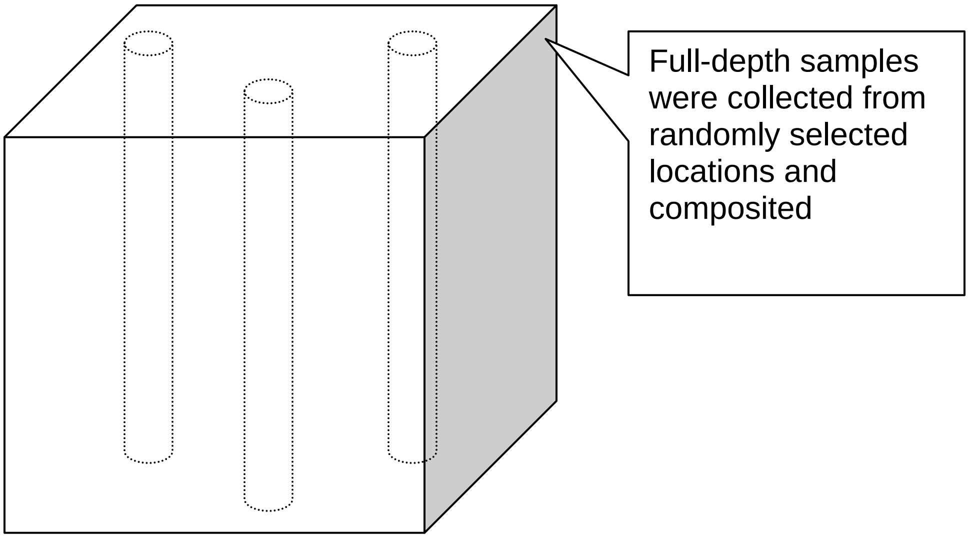
4.4.1 Initial Material Collection and Characterization

The traction sand to be used for this test program was collected by the Principal Investigator from the West Vail Pass roadside. On October 15th, 2008, collected used traction sand to be used in the testing protocol. The sand was collected at approximately mile marker 187.5 on I-70. Weather conditions during the sampling were normal for the time of year. In preparation for a small asphalt project, the traction sand on the roadside was swept and temporarily stored in piles on the asphalt shoulders. This material was used as the testing medium. The material was loaded into four 31-gallon Rubbermaid® tubs through hand shoveling. The test chambers were loaded to within eight inches of the top and special attention was given to avoid soil compaction. Approximately 3.5 cubic feet of sand was placed into each test chamber. The tubs were then transported to the testing site at the I-70 and Havana St. CDOT Maintenance Yard.

The material is typical of sand accumulated during normal road maintenance activities from the previous winter and spring and represented the highest potential source of TRPH. The sand likely comprise commingled sands from both sweeping and stormwater runoff management. The sand collected for testing purposes was screened to remove trash and other large material prior to chemical characterization.

One composite sample was collected from each tub. Equal sub-samples were collected from the sand material in the pattern shown in **Figure 4–2**. These sub-samples were combined and analyzed for TRPH (EPA method 418.1). The results of this analysis serves as the baseline condition to be compared against the results from the four experimental chambers.

Figure 4-2 Composite Sampling Approach



4.4.2 Sampling and Analysis During Test Program

Each test chamber was sampled at various times during the test program. Avoidance of sample error was addressed through a sub-sampling approach as characterized in Figure 4-2. Three equal full-depth sub-samples collected from random locations were combined for analytical testing purposes. Composite sampling was conducted at 2 weeks, 1 month, 3 months, and 6 months.

4.5 Location

The location of the experiment was the CDOT I-70 and Havana St. Maintenance Facility. The tubs were located in an isolated area of the facility to avoid impacting maintenance operations. Additionally, the site was open and not shaded to mimic a potential stockpiling situation. Therefore, conditions surrounding the experiment were reflective of potential storage scenarios.

4.6 Duration and Monitoring Data

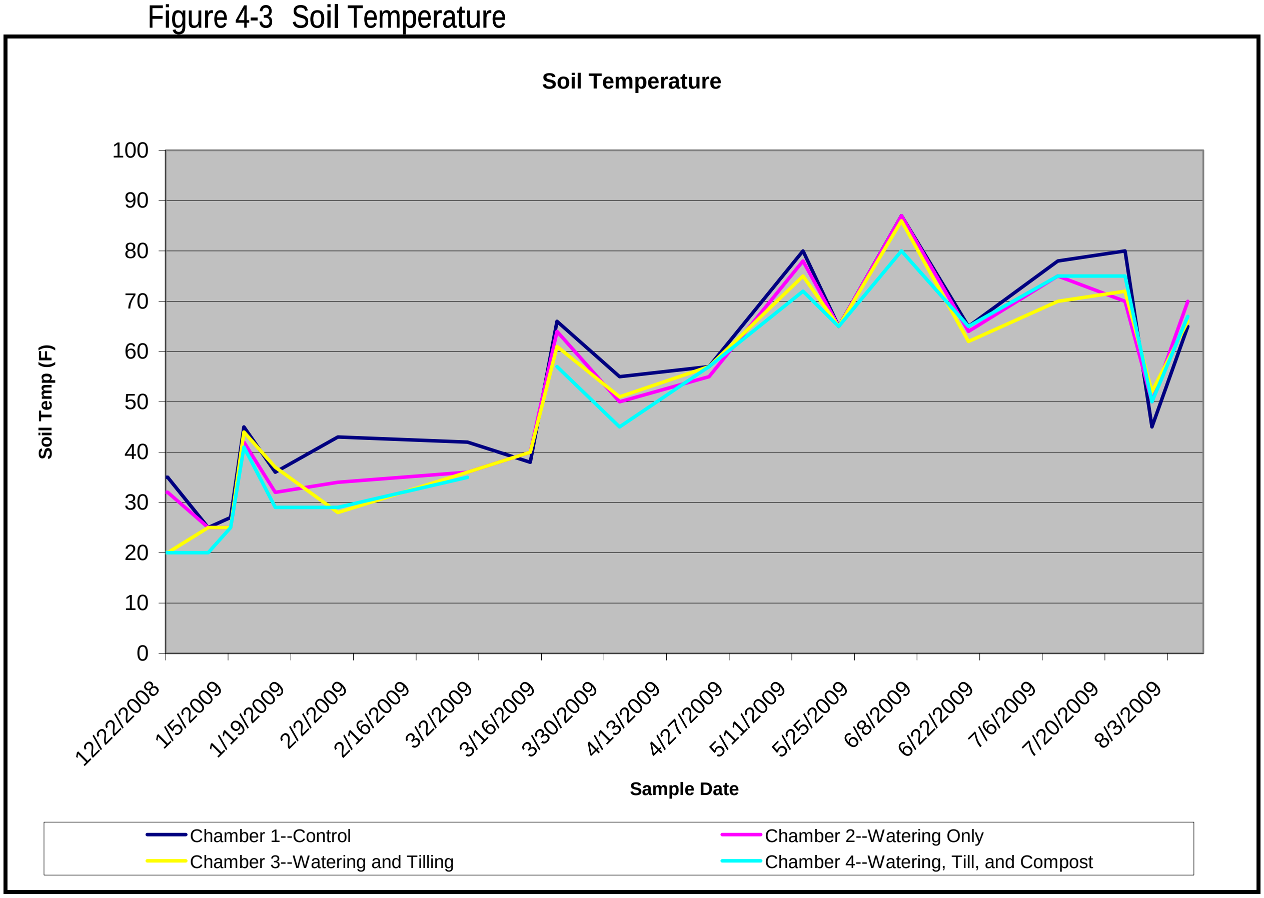
The duration of the experiment was six months. During this period, various data were obtained when the test chambers are routinely visited for maintenance or sample collection:

- Soil moisture
- Soil temperature
- Local rain amount
- General appearance of test chambers
- Photographs of each test chamber

4.7 Results

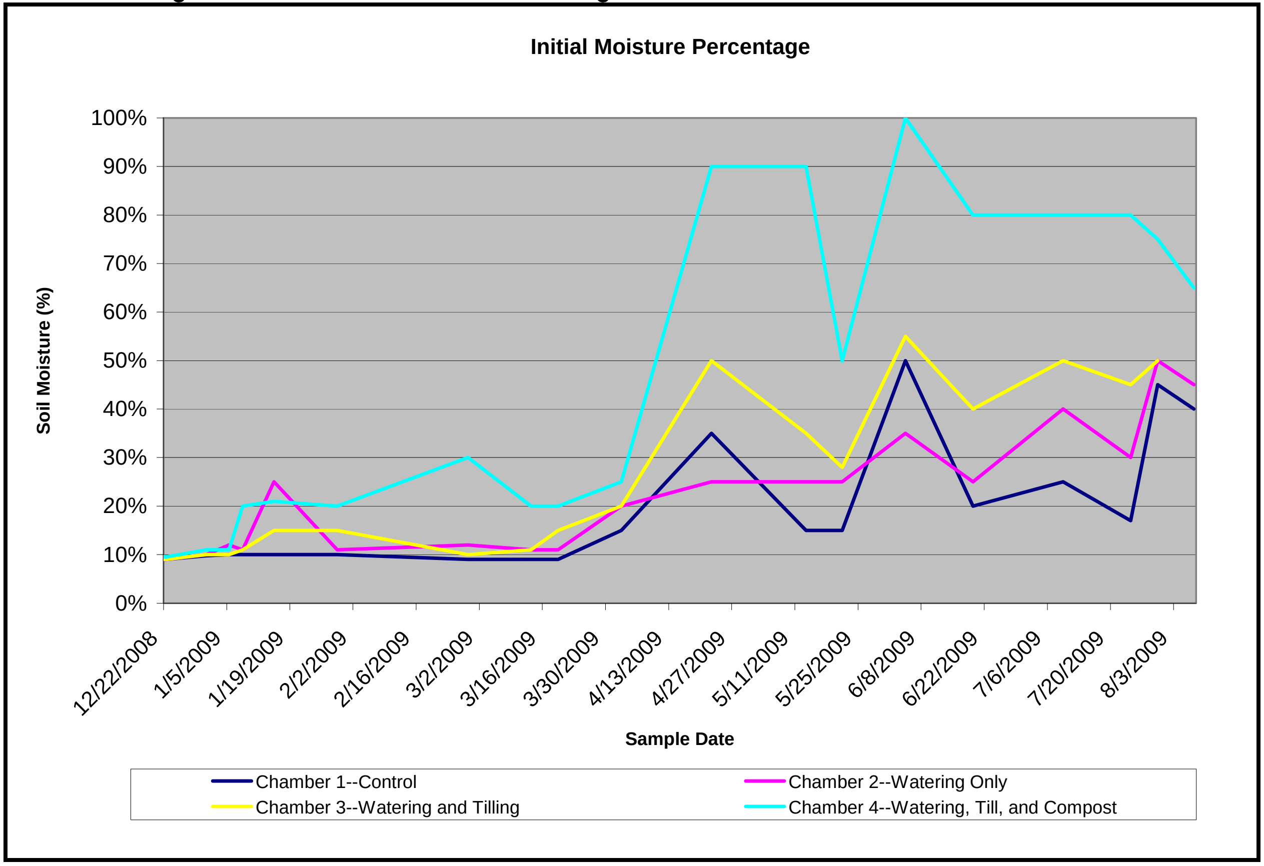
The results of the pilot/ bench test are shown in Figure 4-3 through Figure 4-6 below. Four parameters were monitored including temperature, initial moisture percentage, pH, and TRPH.

Figure 4-3 Soil Temperature



Soil temperature generally increased over the approximately seven month study. Temperature increases are expected during this time as winter transitions from winter to spring to summer. All four chambers showed approximately the same temperature increase pattern. Chamber 1 generally had the highest temperature while Chamber 4 generally had the lowest. The initial hypothesis was that Chamber 4 would have a higher temperature because it was thought that it would have a higher metabolic activity and thus temperature.

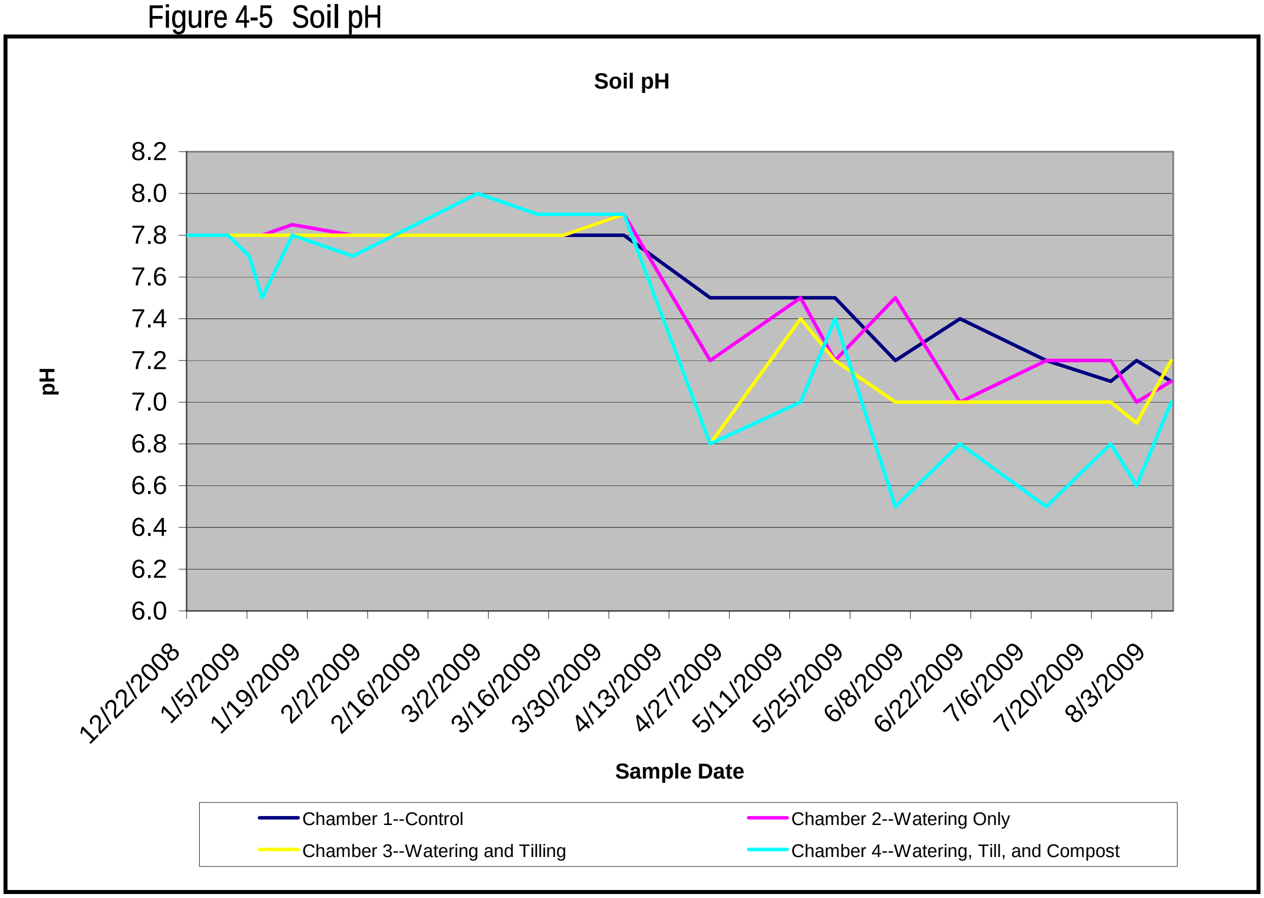
Figure 4-4 Initial Moisture Percentage



Initial moisture percentage data was taken using a moisture probe prior to obtaining samples. A general increase in moisture would be expected in the spring and summer months of the study. During the winter months, much of the material was extremely dense and partially frozen. Limited water was added at that time which would have exacerbated that condition.

Chamber 1 was expected to have the lowest initial moisture percentage due to the fact that the only moisture it received was natural precipitation. Chamber 4 demonstrated significantly higher amounts of moisture in the spring and summer months. The reason for this effect is that compost helps to bind unconsolidated soil/sand particles to retain water and nutrients. This technique is used in gardening and is obvious in this situation. It should be noted that the late winter and spring of 2009 was extremely wet for the Denver metropolitan area. At times, Chamber 2 has less moisture than Chamber 1. The reason this occurred was because Chamber 2 was able to maintain the 20 percent moisture goal, while ambient conditions caused an increase in Chamber 1. It is unknown why there was such variability between the test chambers because their proximity was very close.

Figure 4-5 Soil pH



The pH levels were monitored in all chambers to determine if the levels would change significantly during the study. Throughout the first half of the study, pH levels in all 4 chambers remained relatively steady at a neutral 7.8 for the first half of the study. The pH should be considered if potential uses are for a plant growth medium. It can be concluded that generally the reclaimed sand remains neutral in pH, with a slight overall drop between start and finish. The pH probe used for the first half of the study stopped working about halfway through the study. When a new probe was used, the pH numbers became more volatile. Because of the inconsistencies associated with the pH results, conclusions based on pH activity are questionable and not advised.

Figure 4-6 TRPH Concentration

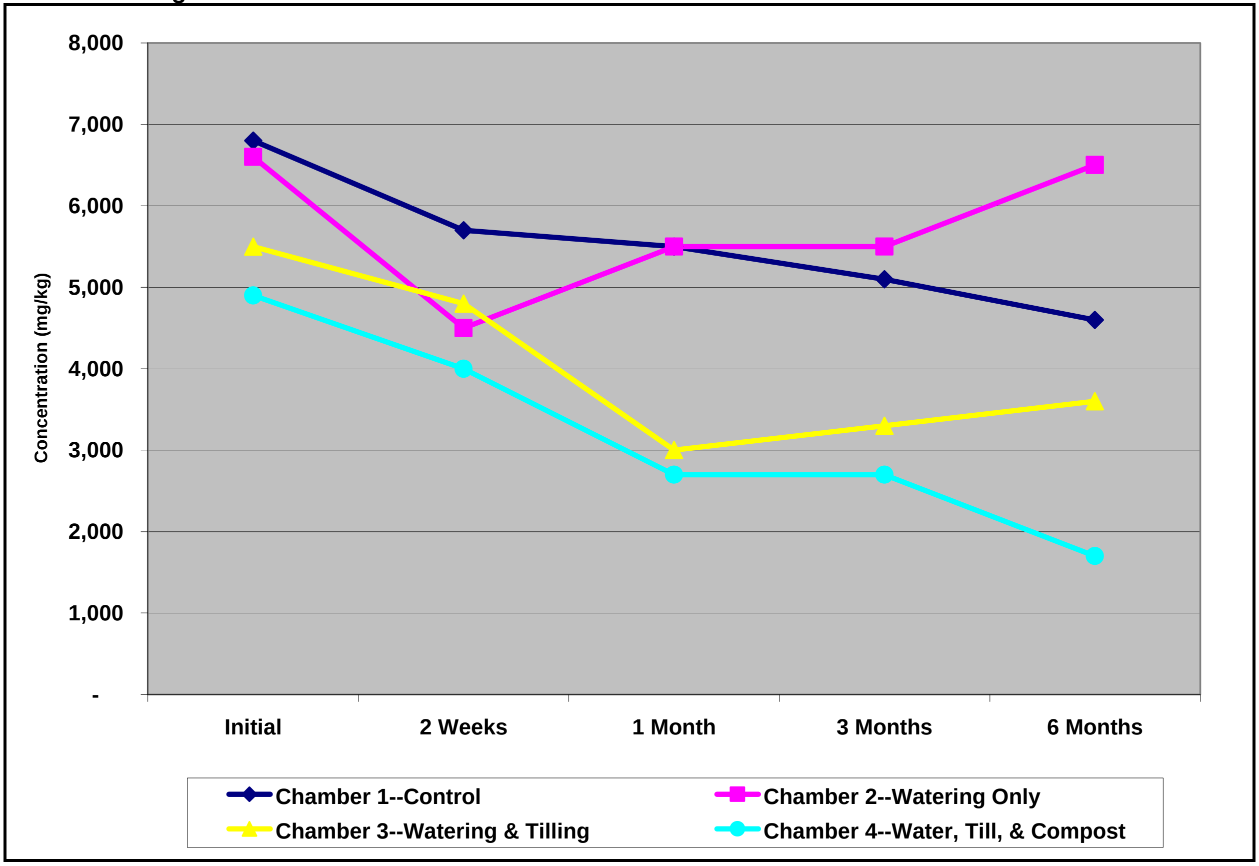


Figure 4-6 presents the TRPH concentrations throughout the length of the study. TRPH concentrations were expected to decrease due to biodegradation by naturally occurring bacteria the sand. While most of the chambers demonstrated a downward trend in TRPH concentration, Chamber 2 ended the study at approximately the same concentration as the beginning. Two possible items could explain this trend in the data. First, the inherent variability of sample collection and the ‘nugget’ effect that was previously described. The second is simply because the natural biodegradation was not as pronounced as initially thought.

Chamber 4 did show the greatest amount of reduction of TRPH concentrations compared to Chambers 1 and 3. This result clearly demonstrates that the addition of BioComp® dramatically increases the rate of biodegradation. Unfortunately, the final TRPH concentration is still elevated above the 500 mg/kg regulatory clean-up level. Total TRPH reduction is presented in Table 4-1.

Table 4-1 Total TRPH Reduction

	Chamber 1-Control	Chamber 2-Water	Chamber 3-Water and Till	Chamber 4 – Water/Till/Compost
Overall Reduction	32%	2%	35%	65%

Because of the mixed results of the testing, overall reduction, but not to below regulatory levels, incorporating any of the actions into the process is not warranted at this time.

5.0 MARKET ANALYSIS

The final step in determining possible re-use options for used traction sand was to conduct a market analysis to identify potential common uses. Recycled Materials Company, Inc. assisted the Principal Investigator with the development of the Market Analysis step. The market analysis focused on potential uses in CDOT practices or construction activities. This was selected as the focus because it represents the highest value for CDOT because it would reduce the costs associated with disposing of the reclaimed sand, as well as create a viable product that CDOT would normally purchase. This resulted in focusing the analysis on various CDOT approved aggregate base course (ABC) materials.

The market analysis included two exercises: 1) determine the process removing trash and other larger debris from the reclaimed traction sand and 2) determine which CDOT specifications could be met with the addition of varying amounts of “virgin” coarse aggregate (c/a). The additional of c/a material was considered to be a practical solution because it increases the number of CDOT c/a specifications met by the material, thus increasing the marketability of the reclaimed sand. After this was conducted, the costs associated with both actions was considered and compared to get an effective cost/benefit analysis.

It should be noted that several initial assumptions were made which were applied in the market analysis:

- 5,000 tons of traction sand and debris is stockpiled at various CDOT maintenance facilities
- 4,750 tons useable traction sand remaining after screening out debris
- Screened out debris (250 tons) could be handled in the following ways:
  - 175 tons of over-sized rock (greater than 0.5 inches) could be used as structural backfill
  - 75 tons would be inert/deleterious trash to be disposed at a landfill
- 10 percent contingency factor added to all costs

In order to determine the actions for and cost of preparing the reclaimed traction sand, four activities were examined: mobilization, re-screening, adding coarse aggregate, and washing and re-screening traction sand. The remainder of this section discusses the four activities and their associated costs. These activities and costs were used to populate the information in Table 5-2 and Table 5-3, respectively.

5.1 Mobilization

The first factor associated with the market analysis is the consideration of mobilizing the necessary equipment and staff to a storage site to prepare for the reclaimed traction sand re-screening activities. The cost of mobilization was determined by factoring in the following parameters.

- Average travel to maintenance facility: 75 miles
- Equipment needed: Mobile screen plant, (2) five cubic yard front end loaders, miscellaneous support equipment, mechanic truck with portable shop trailer, tractor and side dump trailer
- Crew size: 4 people
- Time to complete: 2 days

The estimated mobilization cost also includes obtaining necessary travel permits, plant and stockpile site preparation, mobile screen plant set-up and dismantle, and site clean-up. Based on these assumptions, the unit cost for mobilization is $3.85 per ton. As quantities vary, the price could range from $2.50 to $5.00 per ton.

5.2 Re-Screening

Once the equipment and staff are at the storage site, the sand needs to be re-screened to remove unwanted items like larger particles and unwanted trash and debris. As previously stated, it was assumed that this process would yield 4,750 tons of usable material, 175 tons of oversized rock, and 75 tons of trash. The cost of re-screening was determined by factoring the following parameters:

- Equipment: mobile screen plant, five-cubic yard loader for loading, and (1) cubic yard loader for stockpiling
- Crew Size: 4 people
- Time to complete: 5 days

The cost of re-screening is estimated to be $6.45 per ton, but could range from $5.50 to $8.00 per ton depending on the amount of material. Figure 5-1 show examples of the machinery associated with the mobile screen plant. It should be noted that CDOT could complete the stockpiling with CDOT equipment, and lessen the re-screening cost by $1.15 per ton. This cost savings is based on the assumptions of 38 hours of work to produce 4,750 tons of re-screened sand with a 5-cubic yard loader ($105/hour), and a crew cost of approximately $38/hour. These costs represent an outside contractor performing these actions; removing these costs on a per ton basis (via use of CDOT personnel and equipment) results in the $1.15/ton cost savings.

Figure 5-1 Photographs of Mobile Screen Plant

5.3 *Addition of Coarse Aggregate*

The addition of varying percentages of dry screened rock to the reclaimed traction sand will generate several higher valued end use materials when the co-mingled materials are re-screened. In order to estimate the costs of these comingled materials, the same assumptions were applied. The same production rates would apply and the same equipment and crews would be utilized. Additional assumptions are as follows:

- “Virgin” coarse aggregate is available within 40 miles of traction sand storage
- Coarse aggregate is fed simultaneously to the screen with reclaimed traction sand to yield a material that meets one or more CDOT specifications.

Table 5-1 presents the physical properties (sieve analysis) for reclaimed traction sand and coarse aggregate prior to any mixing.

Table 5-1 Physical Properties of Reclaimed Traction Sand and Coarse Aggregate

CDOT Classification	Sieve Size (Percent Passing)								
	3”	2”	1”	¾”	½”	#4	#8	#50	#200
Reclaimed Traction Sand	100%	100%	100%	100%	99%	92%	80%	35%	9%
Coarse Aggregate*	100%	100%	100%	100%	21%	1%	1%	1%	1%

* Meets American Association of State Highway Transportation Officials (AASHTO) M-43 #67

Table 5-2 summarizes the materials which could be made by co-mingling various amounts of the reclaimed traction sand and virgin coarse aggregate. The first row in each grouping represents the anticipated physical characteristics (i.e., passing sieve size) of the two materials. These were calculated using a weighted average of the results from **Table 5-1** and how much of each material is in the subsequent mixture. The remaining rows in each group show acceptable ranges of each CDOT Specification in the last column. Only specifications that were met are presented.

Table 5-2 Possible Uses for Salvaged Traction Sand with the Addition of Coarse Aggregate

Coarse Aggregate Supplement[1]	Salvaged Traction Sand	Sieve Size (Percent Passing)									
		3 in.	2 in.	1 in.	3/4 in.	1/2 in.	#4	#8	#50	#200	Matching CDOT Specification
0%	*100%*	*100*	*100*	*100*	*100*	*99*	*92*	*80*	*35*	*9*	
		100								3-15	ABC (Class 2) Master Range
										20	ABC (Class 3) Master Range
					100			20-85		5-15	ABC (Class 7) Master Range
			100				30-100		10-60	5-20	Structural Backfill
				100						2-10	Structural Backfill (Flow Fill Conc) (206.02)
											Median Cover Aggregate (703.10)
25%	*75%*			*100*			*70*			*7*	
				100			30-70			3-15	ABC (Class 5) Master Range
33%	*67%*		*100*	*100*	*100*		*62*	*54*		*6*	
		100	95-100				30-65			3-15	ABC (Class 1) Master Range
					100		30-65	25-55		3-12	ABC (Class 6) Master Range
33%	*67%*		*100*				*62*			*6*	
			100				20-65			0-10	Bed Course Material (703.10 b)
40%	*60%*				*100*	*100*		*49*		*5*	
					100	90-100		28-58		2-10	Grading SX Master Range (703.4)
65%	*35%*		*100*	*97*	*90*		*37*			*4*	
			100	90-100	50-90		30-50			3-12	ABC (Class 4) Master Range

▨ = Estimated co-mingled material at the percentages in the left column.

ABC = aggregate base course

1. Meets AASHTO M-43 #67
2. Specifications taken from Table 703-3, unless otherwise noted.

TRPH concentrations may be a concern for any of the above uses. CDPHE requires their approval prior to CDOT's re-use of any traction sand material. Details of the approval process are presented in **Section 6.1**. Additionally, the total organic carbon (TOC) in the reclaimed traction sand averages to approximately 1 percent (**Table 3-1**) and should not be a concern for structural backfill.

A number of course aggregate material specifications could not be met with either 100 percent of the reclaimed traction sand or any mixture of the supplement material. The following list represents the applications where reclaimed traction sand is not suitable:

- Hot Mix Asphalt (703.4)
- Stone Matrix (703.5)
- Cover Coat Aggregate (703.6)
- Mineral Filler (703.6)
- Filter Material (703.7)
- Concrete Aggregate (601)

5.4 Cost/Benefit Analysis

The final step in the market analysis was to perform a cost/benefit analysis to determine how effective and realistic the re-use of traction sand would be. Using the previously discussed methods as a basis to determine the costs of preparing the traction sand for re-use, this section presents the results of the cost/benefit analysis.

In order to determine the costs associated with the materials in **Table 5-2**, it was necessary to consider the entirety of the costs from the process. This included costs of the coarse aggregate supplement, the costs associated with preparing the salvaged traction sand, and the costs of 'virgin' material for each matching CDOT Specification. **Table 5-3** presents the total costs for reclaimed traction sand compared to the cost of "virgin" materials for the CDOT Specifications that are met in **Table 5-2**.

A summary of the costs associated with reclaiming traction sand and the costs of virgin material is presented in **Figure 5-2**. In most cases, using the reclaimed sand is more cost effective than purchasing virgin coarse aggregate material. Only in three cases does using reclaimed traction sand cost more than virgin material ABC Class 1, ABC Class 4, and Bed Course Material. The only reclaimed material with a significant cost increase over virgin material is ABC Class 4, which is approximately 34% higher to use the reclaimed traction sand.

The greatest cost savings for using reclaimed traction sand is as Median Cover Aggregate at a cost savings of 23%. Using reclaimed traction sand as ABC Class 2, Structure Backfill Class 1 and Structure Backfill (Flow Fill Concrete) all result in a cost savings of 16% over purchasing virgin material.

5.5 Wash and Re-Screen Traction Sand

If CDOT desires to use the salvaged traction sand in structural concrete mix design, it would be necessary to wash the material to eliminate chlorides which have been mixed with the original sand. The presence of chlorides inhibits the hydration of the concrete mix. There is also significant potential for oxidation when in contact with imbedded or abutted steel. Further testing would be required to determine the degree of the effects and mitigating efforts.

The cost to wash and rescreen the collected traction sand is $15.50 per ton. As quantities vary, the re-screening and clean up costs should remain within a range of $14.00 - $24.00 per ton.

Table 5-3 Costs of Reclaimed Traction Sand Compared to “Virgin” Traction Sand costs

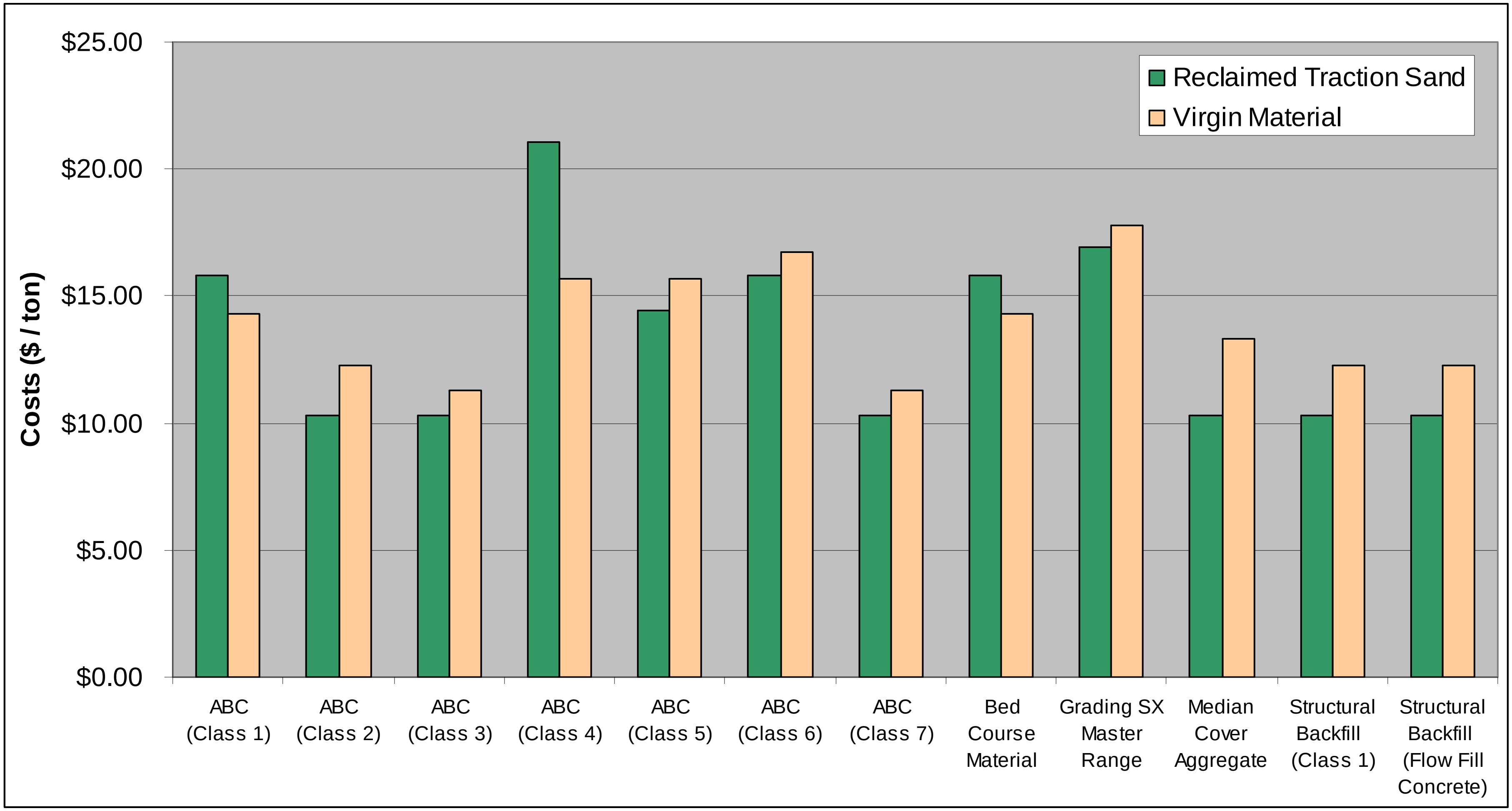
	Coarse Aggregate [1]			Traction Sand		Coarse Aggregate and Sand Mixture			“Virgin” Traction Sand Cost ($/ton) [5]	Percent Cost Savings (Overrun)
CDOT Specification[2]	Percent of Mixture	Unit Cost ($/ton)	Prorated Cost ($/ton)	Percent of Mixture	Prorated Cost ($/ton)[6]	Mobilization Cost ($/ton) [3]	Rescreening Cost ($/ton)	Total Reclaimed Sand Cost ($/ton) [4]		
ABC (Class 2) Master Range	0%	$23	N/A	100%	$0	$3.85	$6.45	$10.30	$ 12.30	16%
ABC (Class 3) Master Range	0%	$23	N/A	100%	$0	$3.85	$6.45	$10.30	$ 11.30	9%
ABC (Class 7) Master Range	0%	$23	N/A	100%	$0	$3.85	$6.45	$10.30	$ 11.30	9%
Structural Backfill - (Class 1) 703.08(a)	0%	$23	N/A	100%	$0	$3.85	$6.45	$10.30	$ 12.30	16%
Structural Backfill (Flow Fill Concrete) (206.02)	0%	$23	N/A	100%	$0	$3.85	$6.45	$10.30	$ 12.30	16%
Median Cover Aggregate (703.10)	0%	$23	N/A	100%	$0	$3.85	$6.45	$10.30	$ 13.30	23%
ABC (Class 5) Master Range	25%	$23	$5.75	75%	$0	$3.85	$ 4.85	$ 14.45	$ 15.70	9%
Grading SX Master Range (703.4)	40%	$23	$9.20	60%	$0	$3.85	$ 3.90	$ 16.95	$ 17.75	5%
ABC (Class 6) Master Range	33%	$23	$7.60	67%	$0	$3.85	$ 4.35	$ 15.80	$ 16.70	5%
Bed Course Material (703.10 b)*	33%	$23	$7.60	67%	$0	$3.85	$ 4.35	$ 15.80	$ 14.30	(9%)
ABC (Class 1) Master Range*	33%	$23	$7.60	67%	$0	$3.85	$ 4.35	$ 15.80	$ 14.30	(10%)
ABC (Class 4) Master Range*	65%	$23	$14.95	35%	$0	$3.85	$ 2.25	$ 21.05	$ 15.70	(34%)

ABC = aggregate base course

1. Meets AASHTO M-43 No. 67
2. Specifications taken from Table 703-3, unless otherwise noted.
3. Assumes Unit Cost to rescreen is $6.45 per ton, multiplied by percent traction sand of mixture
4. Prorated Coarse Aggregate Cost + Prorated Sand Cost + Mobilization + Rescreening
5. Assumes market value for material purchase, $7.15 per ton to haul 40 miles to site, and $1.15 per ton to stockpile at site
6. Assumes cost of collection from road, transportation, or other treatment is already accounted for in other practices and documented in the Maintenance Level of Service.

* Cost of reclaimed sand is higher than virgin material

Figure 5-2 Costs of Reclaiming Traction Sand and Costs of Virgin Material



ABC = aggregate base course

6.0 BENEFICIAL RE-USE APPROVAL PROCESS

Once CDOT has decided upon the course of action for traction sand re-use, solid waste regulations require CDPHE's approval prior to active use of reclaimed traction sand. Through multiple meetings with David Snapp, CDPHE Solid and Hazardous Waste Division, it was determined that the application should be composed of a cover letter explaining CDOT's intended use for the reclaimed sand, and should be accompanied by any relevant technical analysis, such as this report (Personal Communication, 2010).

CDPHE also indicated that they require laboratory testing for volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs), and may require follow-up testing based on the VOC and SVOC results. The intent of this supplemental sampling is to verify that no organic constituents are present at levels that may pose an adverse health risk or a higher incidence of carcinogenic effects. Therefore, the sampled traction sand should be compared to the CSEVs for SVOCs and VOCs. If the results indicate that the sand contains constituents less than the CSEVs, then CDPHE will likely approve the proposed re-use option. Additionally, based on the results of the supplementation sampling, CDPHE may require that additional sampling be conducted until they determine that no additionally sampling is required (Personal Communication, 2010).

During the additional coordination with CDPHE some additional questions to be resolved with CDPHE are:

1. Can the reclaimed traction sand be mixed with virgin material to reduce the TRPH concentrations below 500 mg/kg?
2. Do other CDPHE units (e.g., air quality, water) support this re-use concept?

7.0 CONCLUSIONS AND RECOMMENDATIONS

The presented information shows that no excessive metal contamination, above what would naturally occur is present in the traction sand. Petroleum hydrocarbons and O&G are anthropogenic, or introduced, contaminants detected in the traction sand samples. There appears to be a concentration gradient for these constituents from the roadway with higher concentrations to the basins with lower concentrations. The presence of petroleum hydrocarbons and O&G in traction sand may present a limitation in the potential re-use options. Prior to the use of any salvaged traction sand material, federal and state regulations require that the material be approved by CDPHE for beneficial re-use.

Based upon the information presented in this document, Table 7-1 presents the recommended re-use options for reclaimed traction sand and the quantities used by CDOT in 2009. These uses are selected based on the ability of the traction sand to be supplemented to meet CDOT's aggregate specifications and a positive cost/benefit analysis when compared to purchasing virgin materials. Re-use options that cost more than 10 percent than purchasing virgin materials were not recommended; the 10 percent cutoff corresponds to the 10 percent contingency included in the cost/benefit analysis.

Table 7-1 Recommended Uses of Reclaimed Traction Sand

CDOT Aggregate Specification	Common Uses	Quantities Used by CDOT in 2009 (tons[2])
ABC (Class 2)	Not commonly used, but would be road base	174
ABC (Class 3)	Not commonly used, but would be road base	15,728
ABC (Class 5)	Road Base, tends to be used in Mountains	20,913
ABC (Class 6)	Road Base, Extremely Common on Front Range	312,460
ABC (Class 7)	Not commonly used, but would be road base	6,625
Bed Course Material[1]	Pipe Bedding, structural backfill Class 1 can pass for this material	122
Grading SX Master Range	SX is a ½" max. aggregate size asphalt mix, top lifts	825,733
Median Cover Aggregate	In concrete used to fill in raised islands	23
Structural Backfill (Class 1)[1]	Bridge or Retaining Wall Select Backfill, Pipe Bedding and Backfill	198,227
Structural Backfill (Flow Fill Concrete)	Pipe or Inlet Backfill within Streets, Bridge Backfill	NA[3]

1. Cost of reclaimed sand is higher than virgin material
2. Some quantities converted from cubic yards assuming 1 cubic yard = 1.5 tons of sand
3. Information not available at this time

8.0 REFERENCES

Boerngen, Josephine G., and Shacklette, Hansford T., 1981, Chemical analyses of soils and other surficial materials of the conterminous United States: U.S. Geological Survey Open-File Report 81-197, U.S. Geological Survey, Denver, CO.

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Smith, David B., William F. Cannon, Laurel G. Woodruff, Robert G. Garrett, Rodney Klassen, James E. Kilburn, John D. Horton, Harley D. King, Martin B. Goldhaber, and Jean M. Morrison. 2005. Major- and Trace-Element Concentrations in Soils from Two Continental-Scale Transects of the United States and Canada. USGS Open-File Report 2005–1253.

APPENDIX A

Literature Search

Summary of Literature Search Results for Traction Sand Reuse Options

Source	Types of Reuses	Advantages	Disadvantages	Costs per Ton	Findings
Montana DOT	Mixed with seed for vegetative cover in the highway median	Eliminates noxious weed growth	Costly method	$50 total $3.50/ton for screening material	Reuse of traction sand is being done on a small scale; a percentage of the good recycled sand is mixed with "new" material every year.
City of Edmonton	Traction sand other non highway uses	Lessens the amount going to the dump	Costly method	$50	Reuse of traction sand is being done on a large scale and has been since the mid 1980's
California DOT	Sand is sent to a pick up location and placed in stockpiles in preparation for Teichert Aggregate company to pick up and re-use in their operations.	Inexpensive way to dispose of material for the agency	None-material is claimed by local Aggregate co Costly disposal method of material will eventually overwhelm local landfills company		Teichert Aggregate company is using the material for mine reclamation. Becky Wood Enviro. Mgr.
City of Fort Collins	None	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		All sweepings are sent to a landfill
City of Greeley	None	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		Sweepings are screened and sent to a landfill. Straight Salt is predominantly used
City of Reno	None	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		All sweepings are sent to a landfill
City of South Lake Tahoe	None	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		Less sand usage, sweepings are sent to a landfill
Alaska DOT	None	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		Snow and traction sand are placed in "Snow Stockpiles" throughout the city; after they melt the sweepings are put into the landfill
Idaho DOT	None-Study proved to be too costly for the state.	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		Traction sand has been all but eliminated from use. The only exception is when the temperature drops to 15 degrees or lower.
Minnesota DOT	None	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		Sweepings are sent to a landfill
New York DOT	Unable to locate contact				
Oregon DOT	None	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		Less sand usage overall, using a slurry mixture. Sweepings are sent to a landfill.
Utah DOT	None	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		Sweepings are sent to a landfill
Vermont DOT	None	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		Sent to a local dump site, no re-use is performed
Washington DOT	None	Easy method of disposal	Costly disposal method of material will eventually overwhelm local landfills		Less sand usage, sweepings are sent to a landfill. Salt slurry mixture is used

APPENDIX B

Traction Sand Sampling Protocol and Sampling Photographs

Sampling Plan for CDOT Sand
H.L.O. Huyck

This plan is written in a memo in order to provide consistent sampling procedures for used CDOT traction sand. This will allow the analyses to be comparable.

1. Sample Sites and Sub-Samples

Introduction: (See Table of Sample Sites at end.)Each sample location or site is a large area along both sides of a highway. One sample site may be several miles long. For example, the "Berthoud East" site on US 40 stretches from the base of the climb (just west of Berthoud Falls) to Berthoud Pass. This sample covers about 5 miles of road. Because of the large size of each site, there are several sub-sites. Eight, well-spaced sub-sites provide enough variety to obtain a representative sample. Location and mileage at each sub-site should be noted. Then, within each site at least 4 scoops of sand, separated by at least 5 feet. If the sub-site is large, scoops may be taken 10 or 20 feet apart. Measure the length between sample scoops either with a tape measure or (if you know your pace length well) by pacing off the same spacing between each scoop. So, the location – sub-site – scoop hierarchy is as follows:

Sample Location/Site
(several miles of highway or several sediment basins)
|
|
V
Sample Sub-site
(**8** per sample location-see table below)
|
|
V
Sample Scoops
(**4 per site**, spaced apart 5, 10, or 20 feet, depending on the length of the sub-site)

This sampling system provides the minimum of 32 scoops per sample location, which is needed to provide statistical accuracy* (4 scoops per site) and to reach the necessary 40-pound-per-sample.

2. Sampling Preparation

a. Use two LARGE coolers for the samples and add blue ice packets to keep samples COLD. There will be 4 location samples total, but R-value will be measured on 2 location samples. So, each location sample needs to contain a **minimum** of 40 pounds of traction sand per location sample. The R-value and sieving requires a minimum of 60 pounds of sample, and the chemistry requires about 8 pounds. A location sample of 32, 1-cup scoops should weigh about 35 pounds, so you should have plenty if you sample correctly.
b. Best sample holders are 2, 2-gallon Ziplock freezer bags, nested inside each other. You will need 2 holders per sample site. Put 4 sub-site samples in each holder. LABEL each sample bag with its sample site or sub-site location.
c. Find at least 8 sub-sites in the sample area that should be spaced evenly along the total site area. (Note: even spacing includes having about half of the sub-sites on

either side of the highway, particularly for interstates. Keep in mind where sampling can occur **SAFELY—**e.g. near pullovers, rest stops, ramps, where the shoulder is wider than usual.)

d. At each sub-site, sample at least 4, 1-cup scoops, spaced at least 5 feet apart. Sample anything that fits inside the scoop (including cigarette buts, bits of asphalt, and other litter). If it does NOT fit, leave it out, but note that on the Sampling Form. For example, some tree branches may be in the area. They will not fit the sample, but should be noted. If a tire chain, fan belt, or other sizeable item is in the sub-site, pick it up and include it in the 5-gallon bucket for the R-value test (see below).
e. Use Sampling Form to track sub-samples within each sample site and to describe any useful information (e.g. from an old pile or recently scraped sand on roadside.) Note if there is any litter or tree material that is too big to include in the sample. If possible, estimate the percent volume of that material on the form.

3. Sampling at Each Location:

a. Obtain a topographic map of the area and make copies large enough to put sand locations on it. (A 140% increase from the 1:24,000, or 7.5 minute USGS topo. sheets works well. You may need several 11 x 17 sheets to cover one site.)
b. Bring a sampling form to note: approximate milepost, car mileage, side of road, and description of site. A general sketch of the sample sub-site can fit on the forms.
c. Bring Sharpies and masking tape to mark the bags.
d. Note vehicle mileage for starting point (at a milepost at one end of the location) and at each site. If sampling basins, note basin number (if available) in addition to mileage.
e. Bring a measuring tape to show the length along a sub-site, and to space scoops equally along the site. (If you know your pacing space, use that to save time.)
f. Bring 2 1-cup scoops so that if one wears out, the other is available. Bring something flat to scrape off the top for consistent sample size from each site. (A trowel works well.)
g. Take a minimum of 32 scoops for the entire site to ensure enough material is available for the sample analyses and tests. The 32 scoops per site are needed to ensure enough heterogeneity of the sample (per Smith et al., 2000) and enough sample for R-value test.
h. Label each composite sample.
i. Place each sample bag in a cooler with blue ice packets to maintain constant, cool temperature.
j. If the sub-site includes litter, bits of chain, or tire pieces, pick up a small amount for inclusion in the R-value test.

4. Splitting Composite Samples

a. If the contract lab will split the samples into sub-samples, then you only need to do the first split for the R-Value and physical testing.
b. Splitting may be done using splitters or by rolling samples on plastic (first one way, then at right angles) to thoroughly mix, then dividing the sample in half. Put one half in the R-value bucket and split the remainder until you reach the 1-quart

amount for chemical analysis. Use heavy plastic so it does not break under the sample weight.

c. Split **half** of the composite sample for the R-Value and any other physical tests. Split the remaining half and put one half of that into the R-Value bucket. This means that ¾ of the sample will go in the bucket. Since the CDOT lab needs at least 60 pounds. The R-value sample goes into a **5-gallon bucket**. Add to the bucket the bits of litter, chain, tire, etc. (see #3j) collected for the R-value test. Since the sample is probably in 2 sub-sample bags, split first one, then the other.

d. From the remaining sample, split out about 8 pounds of sample (volume-about one quart) from each sample site for chemical analysis. Place into freezer bags and label with a marker. Use lab labels and fill out Chain-of-Custody forms to go with the samples.

e. Put any remaining material into plastic sample bags and LABEL them for the sample location or sub-sample location.

f. Repeat with the second sub-sample bag, and combine the splits with the labeled samples from the first sub-sample bag.

g. CLEAN the splitters or rolling plastic before splitting the next sample. Brush out well. If the sample is wet, use wet paper towels to clean any remaining material stuck to the sides of the splitter bins, then dry with towels or compressed air (if available).

5. Composite Sample for R-value for potential reuse.

Take enough to create a composite of 60 pounds. This goes to the CDOT R-1 lab for R-value analysis—a structural integrity test to see if the material can be used for road base. For example, for 4 individual samples, then each sample must provide 15 pounds of material to the composite. Mix together in a clean, 5-gallon plastic pail for delivery to CDOT, and include litter from subsites.

6. Deliver Samples

a. Chemical analysis —Take samples to the contract lab.

b. R-Value and physical testing: Deliver the large sample to the R-1 CDOT Materials Lab at 4670 North Holly St., Unit B, Denver, CO. Call ahead to Bill Schiebel to confirm delivery times (303-398-6801).

7. Sample Analyses

a.Contract Lab: chemical analyses-10 samples: 1-10.

- i. Soil pH, saturated paste (USDA No. 60(21A)
- ii. Percent Solids
- iii. Specific Conductivity (EPA Method-M120.1 with saturated paste prep)
- iv. Total Organic matter(TOC-ASA No.9 29-2.2.4 combustion)
- v. Oil and Grease (M9071A- Soxhlet Extraction)
- vi. TPH (EPA Method 8015)
- vii. RCRA 8 metals (total)
- viii. Copper (total, EPA Method M6010B ICP)
- ix. Zinc (total, EPA Method M6010B ICP)

b.CDOT R-1 Materials Lab: R-value and Size sieving.—2 samples: 1+3+5+7+9(roadside samples); and 2+4+6+8+10 (sediment basins)

8. Sample Locations

	MP	Subsample	Sample Sub-sites
US 40 Berthoud Pass East and West			
1.Berthoud Pass East	249.05-243.05 (top of pass)	Westbound	4 sites
		Eastbound	4 sites
2.Berthoud Pass East Basins		Basins	8 basins, evenly spaced top to bottom of pass
3. Berthoud Pass West	(top of pass to big bend at base)	Westbound	4 sites
		Eastbound	4 sites
4. Berthoud Pass West Basins		Basins	4 basins, at MP 237 and 238
I-70 Eisenhower Tunnel East and West			
5. Eisenhower East	216-221	Westbound	4 sites
		Eastbound	4 sites-2 along guardrails
6. Eisenhower East Basins		Basins	4 basins-3 WB at MP215.3-215.8, 1-weirs at base of Loveland Ski EB off ramp
7. Eisenhower West	207-213.5	Westbound	4 sites
		Eastbound	4 sites-2 along guardrails
8. Eisenhower West Basins		Basins	4 basins-#17 (at Hamilton Box) and 3 on frontage road below—evenly spaced (#1, #5, #13)
I-70 Vail Pass West			
9. Vail Pass West	190-180	Westbound	4 sites
		Eastbound	4 sites-2 along guardrail
10. Vail Pass West Basins		Basins	4 westbound, 4 eastbound, staggered on mileposts

* Smith, K., Ramsey, C.A., and Hageman, P.L., 2000, Sampling strategy for the rapid screening of mine-waste dumps on abandoned mine lands: International Conference on Acid Rock Drainage,_____, 9 pp.

SAMPLING PHOTOGRAPHS

Collection Site – Berthoud Pass

Sample Collection – Berthoud Pass

Typical Collection site – Basin

Typical Collection Site – Basin

APPENDIX C

Characterization of Used Traction Sand

DRAFT
CHARACTERIZATION OF USED TRACTION SAND
2008 REPORT

Prepared by Clear Creek Consultants
for
CDOT Region 1 Environmental

15-August-2008

Table of Contents

Executive Summary

Appendix A Traction Sand Sources

Appendix B Sand Disposal Documentation

EXECUTIVE SUMMARY

Used roadway traction sand physical and chemical properties have been measured since 2002 to assess management and disposal options for accumulations along central Colorado mountain roadways. This report provides and update of sampling and analysis results for CDOT used traction sand. It incorporates results from 2005 and 2007, and builds on previous reports entitled "Interim Report on Characterization of CDOT Used Traction Sands and CDOT Characterization of Used Traction Sands" (Huyck, 2003a; 2003e; 2005). Details about sampling procedures and analytical methods are included in other plans (Huyck, 2003b, 2003c).

At least five sand samples have been collected each from four different I-70 mountain pass locations and two Berthoud Pass locations between 2002 and 2007. These include both roadway shoulder and sediment collection basin sand samples. Metal concentrations were low or not detected in most samples. The used traction sand meets RCRA requirements for disposal. Phosphorus and nitrogen concentrations were also low, and the sand was low in salinity. Oil and grease was detectable in sand samples, but at concentrations below regulatory thresholds. Grain size fractions were analyzed to determine if the sand could be reused as "aggregate base course" (road base aggregate for use under paving projects) or as traction sand. Grain sizes and R-value indicate that used traction sand may be reused in Class 7 aggregate base course. Based solely on grain size results from most sample areas, data indicate that approximately 50 percent of the sand could be re-used as traction sand.

1.0 INTRODUCTION

Traction sand is used in large quantities to maintain safety on CDOT mountain roads and highways during the winter. Although rock salt and liquid deicers have reduced the total amount of traction sand used, high sand volumes are required during winter on steep mountain roads to maintain safe mobility. In an effort to reduce the amount of traction sand that reaches streams and wetlands, CDOT has committed significant resources to recovery and disposal of used traction sand. Before disposal however, the sand must be analyzed to ensure that it meets RCRA standards for land disposal. To this end, sand sampling and analysis occurred in 1996, 2002, 2003, 2004, 2005, and 2007. Previous results are reported in Huyck (2003a; 2003e; 2005). This report summarizes the sand sample results for 2005 and 2007 with comparisons to previous sampling years.

Sand analyses focus on whether the sand is "hazardous" by exceeding RCRA limits for specific metals (arsenic, barium, cadmium, chromium, lead, selenium, silver, and mercury), is too salty for plant growth (using conductivity), or is high in oil and grease or total petroleum hydrocarbon. Grains size analyses are used to determine whether the sand meets size specifications suitable for use as aggregate base course or re-use as traction sand (Table 3; specifications from CDOT, 1999, p. 881-882).

2.0 BACKGROUND

Used traction sand has been sampled in several different Colorado mountain highway corridor locations since 2002. Sand deposited along highway shoulders and in sediment collection basins were sampled to assess any differences in chemistry or grain size distribution.

Used traction sand samples were analyzed for RCRA total metals, specific conductivity, recoverable oil and grease, and total phosphorus. Sand grain size fractions were also measured to determine suitability for reuse. Testing and analyses parameters were selected that are of specific interest for sand reuse in particular watersheds. Specific conductivity (as an indicator of total salt content) is used to document suitability for use of the sand as a plant-growth medium. Soil pH indicates whether or not acidity is a problem.

The RCRA metals and oil and grease were analyzed for comparison to hazardous waste regulations. Recoverable oil and grease analysis includes large chain (i.e. nonvolatile) and polar hydrocarbons, but not volatiles. The recoverable oil and grease analyzes for compounds such as asphalt, tar, axle grease, and vehicle oil. Total phosphorus was tested to determine content in sediment as it relates to those found associated with stream TSS concentrations.

2.1 Sampling in 2002

In March 2002, composite samples from six different CDOT sand pile locations within the I-70 and US-40 mountain highway corridors were collected and analyzed with results shown in Table 1. Sand size fraction results are shown in Table 2. Copper and zinc were analyzed because the Clear Creek watershed is the site of some mine Superfund operable units, and the local water quality organizations did not want more metals potentially to be added to the watershed. Used sand from these areas is likely to be placed at the Empire site within the Clear Creek watershed.

Chloride, magnesium and sodium were analyzed (in 2002 only) because they are major constituents for deicers. However, magnesium and sodium are also common in rocks and soil. Since the amount of chloride correlates well with conductivity, the conductivity has been used for later sampling.

Samples that may be placed at the Empire site were also analyzed for total and dissolved nitrogen and phosphorus. The Clear Creek Watershed is monitoring for these nutrients because there is concern that they may impact water quality in downstream lakes and reservoirs. Dissolved nutrients were also analyzed because they are the more mobile form that could potentially migrate to the streams in the Clear Creek watershed. In order to produce results that are consistent with ongoing water quality monitoring, samples were prepared for analyzing dissolved nutrients and then analyzed by the cities of Westminster, and Northglenn. Sample preparation protocols are described in Huyck (2003c).

These analyses represent a significant investment by CDOT to make sure that the sand is safe for disposal within the Clear Creek watershed, and will not create negative impacts on water quality that is of concern to water users.

Sand grain size fractions and angularity were analyzed to determine if the sand could be reused as traction sand. Sieve test results are reported in the table below and depicted graphically on Figures 1 through 3 for the I-70 Vail Pass, I-70 Eisenhower Tunnel, and US-40 Berthoud Pass areas. The CDOT specifications for traction sand grain size requirements are also shown on the table. The minimum acceptable grain size of 0.85 mm (0.03-in) is plotted as a red line on the graphs, indicating right of the line the percentage of used sand suitable for reuse as traction sand.

CDOT Used Traction Sand Size Characteristics - - 2002

Values are the percent finer than the sieve/particle size.***

			CDOT Spec.#1 for Mt. sand	**CDOT Spec.#2 for Mt. sand**	**I-70, Frisco to Copper Mountain**	**I-70, East Eisenhower**	**US 40, Empire-Berthoud Falls**	**US 40, Berthoud Pass East**	**US 40, Berthoud Pass West**	**SH9, Hoosier Pass North**
Source					Everest	Ready Mix	Ready Mix	Ready Mix	Ready Mix	ACA
Shape (>#10)			Angular	Angular	Sub-angular	Sub-angular	Sub-rounded	Sub-rounded	Sub-rounded	Sub-angular
Sieve Size	Particle Size, um									
3/ 4 inch	19,000	|			100	100	100	100	100	100
3/8 inch	9,500	gravel	100	100	94.6	98.8	97.3	98.6	99.4	99.5
#4	4,750	|	60-90		84.1	87.5	85.8	86.4	79.7	83.7
#10	2,000	V	5-60*	20-80*	62.4	58.3	41.2	45.4	32.3	54.9
#20	850	|	0-30**		44.8	39.8	19.8	26.7	14.9	33.0
#40	425	|			28.1	25.4	10.9	16.8	8.8	21.2
#60	250	sand			18.9	17.3	7.3	11.7	6.2	15.4
#100	150	|			12.9	12.4	5.4	8.5	4.5	11.1
#200	75	V	0-2	0-2	8.9	9.2	4.1	6.2	3.1	7.8
Hydrometer	38.2	|			4.3	4.0	1.4	2.8	2.2	4.3
|	24.3	|			3.7	3.3	1.2	2.4	1.6	3.2
|	14.1	silt			3.0	3.0	0.9	1.8	1.1	2.7
|	9.9	|			2.3	2.3	1.0	1.6	1.1	2.2
|	7.1	|			2.1	2.0	0.7	1.3	0.8	1.7
|	3.4	V			1.4	1.4	0.5	0.8	0.3	1.1
V	1.7	clay			1.1	0.7	0.3	0.6	0.0	0.0

* Specification for percent passing #8 sieve (2,380 um). ** Specification for percent passing #16 sieve (1,190 um).

***Double line below #20 sieve size indicates the percent of sand that is considered too small for reuse as traction sand

2.2 Sampling in 2003

Sand sampling for 2003 included seven locations within the I-70 and US-40 Berthoud Pass mountain corridors as shown in Table 1. Samples located in the Clear Creek watershed were analyzed for nutrients in accordance with agreements with local authorities that oversee the Empire sand disposal site.

Total organic carbon analyses began in 2003 because of the limits on carbon required by the Class 7 base aggregate specifications. Table 1 shows chemical analyses results for metals and nutrients. The table below compares 2003 sand size fractions with base aggregate size fractions in CDOT specifications.

CDOT Used Traction Sand Size Characteristics - - 2003

Values are the percent finer than the sieve/particle size *except* silt and clay

	CDOT Class 7*	I-70, Copper Mt. to Vail Pass	I-70, Vail Pass to E. Vail	Vail Sand Berm, S. side	I-70, Eisenhower T. East	I-70, Eisenhower T. West	US 40, Berthoud Pass East	US 40, Berthoud Pass West
Source		Everest	Everest	Ready Mix	Ready Mix	Ready Mix	Ready Mix	ACA
Specific Gravity		2.65	2.65	2.65	2.65	2.65	2.65	2.65
Sieve Size								
1 in.	**100**	100	100	100	100	100	100	100
3/ 4 in.		100	100	100	92.6	100	100	100
3/8 in.		98.4	99.5	100	83.9	99.1	99.6	99.3
#4		89.1	88.5	93.2	76.8	89.8	89.2	88.4
#8	**20-85**							
#10		70.6	66.2	72.4	66.2	70.9	65.1	59.5
#20		50.7	45.7	51.2	56.4	49.6	43.0	39.3
#40		33.1	29.0	33.5	47.3	32.4	25.6	25.8
#60		22.4	19.1	22.4	40.0	22.0	16.0	18.1
#80		17.6	14.6	17.4	35.7	17.1	12.0	14.5
#100		15.9	13.1	15.4	33.7	15.1	10.4	13.1
#200	**5-15**	10.9	8.4	10.2	27.3**	10.0	6.7	9.2
% silt		6.9	5.3	6.9	17.8	6.3	4.6	6.9
%clay		4.0	3.1	3.3	9.6	3.7	2.1	2.3

* According to CDOT specifications, Class 7 may not have a Liquid Limit of more than 30. Plasticity index for this class shall not exceed 6. (CDOT, 1999, p. 881-882). **In this sample, percent of fines exceeds the maximum of 15% for CDOT Class 7.

CDOT Specifications are for three potential classes for Aggregate Base Course (CDOT, 1999, p.882)

2.3 Sampling in 2004

Sand sampling results for 2004 are shown in Table 1 and included seven locations from I-70 Vail Pass, I-70 Eisenhower Tunnel, US-40 Berthoud Pass, and SH-9 on Hoosier Pass. The table below compares 2004 sand size fractions with base aggregate size fractions in CDOT specifications.

CDOT Used Traction Sand Size Characteristics - - 2004

Values are the percent finer than the sieve/particle size *except* silt and clay

	CDOT Class 7*	I-70, Vail Pass to E.Vail	I-70, Vail Pass to Officers Gulch	I-70, Eisenhower Tunnel West	I-70, Silver Plume to Empire	US 40, Empire to Berthoud Falls	SH9, Alma to Hoosier Pass
Source		Everest	Everest	Everest	Everest	Everest	Willets
Specific Gravity		2.65	2.65	2.65	2.65	2.65	2.65
Sieve Size							
1 in.	**100**	100	100	100	100	100	100
3/4 in.		100	100	100	100	100	100
3/8 in.		100	100	95.3	96.6	96.9	93.2
#4		92.3	94.5	89.7	89.4	83.6	73.7
#8	**20-85**						
#10		72.2	74.1	74.4	65.2	57.7	48.9
#20		50.7	53.9	54.5	46.3	38.1	29.8
#40		30.4	34.2	33.9	29.1	21.9	17.6
#60		19.8	22.7	22.1	19.7	13.6	12.3
#80		15.3	17.3	16.9	15.6	10.3	10.1
#100		13.5	15.0	14.9	13.9	9.1	9.3
#200	**5-15**	9.2	9.5	10.0	9.8	6.1	7.2

According to CDOT specifications, Class 7 may not have a Liquid Limit of more than 30. Plasticity index for this class shall not exceed 6. (CDOT, 1999, p. 881-882).
CDOT Specifications are for three potential classes for Aggregate Base Course (CDOT, 1999, p.882)

2.4 Sampling in 2005

Sand was sampled in May and July 2005 at eight locations from I-70 Vail Pass west, I-70 Eisenhower Tunnel, US-40 Berthoud Pass, and SH-9 Hoosier Pass. Two of these samples were collected from sediment basins. Sampling results for 2005 are shown in Table 1. The table below compares the 2005 sand size fractions with base aggregate size fractions in CDOT specifications.

CDOT Used Traction Sand Size Characteristics - - 2005

Values are the percent finer than the sieve/particle size *except* silt and clay

	CDOT Class 7*	Composite of all Samples
Sieve Size		
1 in.	**100**	100
3/4 in.		100
3/8 in.		99
#4		92
#8	**20-85**	
#10		76
#20		
#40		35
#60		
#80		
#100		

#200	**5-15**	9

2.5 Sampling in 2007

A total of 10 traction sand samples were obtained from the roadway shoulder and from sand deposited in sediment collection basins located at Eisenhower Tunnel (Interstate 70), Berthoud Pass (US Highway 40), and Vail Pass (Interstate 70). These samples were collected over the three day period between June 27 and 29, 2007. Sample locations included:

Interstate 70 – Eisenhower East/MM 216-221
Interstate 70 – Eisenhower West/MM 207-213
Berthoud Pass – East/MM 249-243
Berthoud Pass – West/MM 236-240
Vail Pass – West/MM 180-190

Each of the above locations was sampled both for road shoulder sand deposits and for sand deposited in sediment basins. Sampling procedures followed the “Sampling Plan for CDOT Sand”, H.L.O. Huyck, June 2007. Heterogeneous composite samples were obtained through a distributed sub-site sampling program within each sample location. The field sampling report is provided in “CDOT Traction Sand Sampling June 2007”, prepared by Clear Creek Consultants, Inc. (CCC, 2007). Sampling results for 2007 are shown in Table 1.

3.0 RESULTS COMPARISON 2002-2007

3.1 Sampling Statistics

Summary statistics for each test parameter (except those not frequently analyzed or not detected) are shown at the bottom of Table 1. Each highway corridor area was sampled from three to five times. This provides information about the variation in sand characteristics for the same location over time (also known as “error”, versus “precision” which refers to analytical errors).

The sample population mean, maximum, minimum, standard deviation, and coefficient of variation are shown for all samples. The mean value describes the average concentration to be expected for the samples while the maximum and minimum provide the range. The standard deviation from the mean is expressed as the coefficient of variation (CV). Generally for water and soil analytical data, a CV of less than 0.5 is relatively low and suggests that only a small deviation from the mean is expected.

Duplicate samples taken in 2003 (I-70, Eisenhower Tunnel East) and 2004 (US 40, Empire to Berthoud Falls) show the variation in results due to different splits of the same samples (Table 1). The duplicate results are close enough to provide confidence in the chemical analysis. However, the duplicates were omitted from the statistical analysis due to uncertainty in the final result.

Another statistical term to address is the “outliers.” Outliers are analytical results that are so far outside the general trends of most samples that they may represent a very unusual item included in the sample, a glitch in the analysis, or both. For this reason, a minimum of three samples from each location are needed to form a statistically reliable analysis and to discover outliers. The 2002 total phosphorus result for I-70 Eisenhower East was lower and considered an outlier omitted from this analysis.

The total phosphorus analyses in 2003 were repeated because the initial results appeared to be higher than 2002 samples. Again, the Eisenhower East sample appears to be odd, with 380 ppm and <5 ppm total phosphorus from the same sample. However, the other samples remained similar when reanalyzed so the 2003 phosphorus results were retained in the analysis. Total phosphorous, which includes both rock mineral and organic material, is one of the more variable constituents tested in sand samples.

3.2 Sand Classification as Solid Waste

Toxic Characteristic Leach Procedure (TCLP) regulated levels designate a waste as “hazardous” if the leachate from the solid waste meets or exceeds the listed concentration. Solid wastes are washed with acidic water that is 20 times the weight of the solid. So if the total metal in the solid is less than 20 times the TCLP regulated concentration listed in Table 1, the solid is not “hazardous” for that metal (USEPA, 1996).

The RCRA metals arsenic, barium, chromium, and lead were present in detectable concentrations in most sand samples. However, all of the sand concentrations were below RCRA regulatory metals levels for hazardous materials. These metal concentrations were relatively low and consistent among sample areas. The coefficient of variation (CV) ranged from 0.38 for chromium and lead to 0.43for barium, showing low variance among different metals and sample locations. These data suggest that metal concentrations are likely associated with the sand geologic parent material.

Cadmium, mercury, selenium, and silver were rarely detected in the sand samples. The reporting limits for mercury and selenium varied slightly over the years due to differences in laboratories. However, detection limits were below regulatory limits such that exceedences could be determined. The 2007 sediment basin sample from west Vail Pass had the only detectable mercury.

Summary statistics are broken out separately for roadway sand, basin sand, and combined results in Table 2. No obvious distinction could be made between results from roadway sand versus sediment basin sand for the RCRA metals.

All samples contained more than 500 ppm of oil and grease, with an average of 1,825 ppm. As such, all of the used traction sand is classified as “solid waste” and is not considered “clean fill” or “hazardous waste”.

3.3 Non-RCRA Metals Copper and Zinc

Sand sample results for copper and zinc show low concentrations and minimal variance among sample locations (CV<0.5). No pattern existed among sample areas or years, suggesting that these metal concentrations are primarily associated with the sand geologic parent material.

3.4 Salts and pH

The specific conductance shown in Table 1is reported in milliMhos/cm (MMhos). Colorado State Parks’ “Native Plant Revegetation Guide for Colorado” (1998) notes that soils are considered to have salt problems if they are more than 8 milliMhos/cm in specific conductance, plants do not grow well in any soil with more than 6 milliMhos/cm. Since none of the samples is greater than 1 milliMho/cm, they are not too salty to be used effectively for a growth medium.

As a growth medium for native plants in Colorado, pH of soils considered to be “good” is between 6.0 and 8.4. (CDOT specifies a pH of 6.5-7.8 for soils to be used for revegetation on its highway projects—CDOT, 1991.) The chart below shows the ranges of soil pH ratings from Colorado State Parks’ “Native Plant Revegetation Guide for Colorado” (1998).

Soil Ranges for pH for Colorado Native Plants

Unsuitable | Marginally Poor | Fair | Good | Fair | Marginally Poor | Unsuitable

-------------5.0-------------5.5--------**6.0--------8.4**--------8.8-------------9.0-------------

Used traction sand pH analyses indicates the sand tends to be basic (i.e. pH greater than 7.0). The sand pH results range from 7.4 (good) to 9.2 (poor). However, on average the pH of used traction sand was 8.2 which is considered good.

3.5 Total Organic Carbon

For Class 7 aggregate base course, the total organic carbon (TOC) should be ≤ 1-3 % by weight. The TOC analyses results ranged from 0.4% to 2.4% by weight with a mean of 1.0% and within the acceptable range.

3.6 Recoverable Oil and Grease

Oil and grease concentrations ranged from 520 ppm on US40 Berthoud Pass west to 6,200 ppm at I-70 Eisenhower Tunnel east. There was no apparent pattern in the oil and grease concentrations among sample areas or years. The mean concentration of oil and grease for all sand samples was 1,864 ppm. The CV for oil and grease was relatively higher (0.62) than the metals.

As shown in Table 2, the mean concentration was higher in roadway samples (2,029 ppm) versus basin samples (1,211 ppm). The CV was also higher for the roadway samples (0.61) when compared to the basin samples (0.39). This may be caused by the closer proximity to roadway oil and grease sources such as asphalt and vehicles.

According to the Colorado Department of Public Health and Environment (CDPHE), soils (which include sand) with less than 500 ppm oil and grease do not require remediation. Any soils containing more than 500 ppm are considered “solid waste” which may be treated, reused, or disposed of in a manner that is approved by CDPHE. Thus, the used traction sand is considered “solid waste” if disposed, but could be reused in a controlled and CDPHE-approved manner.

3.7 Nutrients (Total and Dissolved)

Dissolved inorganic nitrogen (DIN, Table 1) ranged between 0.03 and 0.46 mg/L. The DIN was lower in 2003 than in 2002. In 2003, Total Dissolved Nitrogen (which includes DIN and organic nitrogen) was also tested. Nitrogen was not analyzed after 2003 because concentrations were low and no pattern was observed in the dissolved nitrate/ ammonia analyses.

Total phosphorus (TP) concentrations ranged from 148 to 1,263 ppm for all samples. The mean TP concentration was 499 ppm. Outlier values (I-70 Eisenhower East 2002) and non-detects (<5 ppm) from 2003 and 2004 were not included in the statistics because they were unreasonably low and inconsistent with other results. No pattern in concentration related to sample area or year was apparent. The sediment basin samples had slightly higher TP concentrations than roadway samples (Table 2).

Dissolved phosphorus concentrations were generally four orders of magnitude lower than the total phosphorus, ranging from 0.0312 to 0.0532 ppm. The large difference observed between total and dissolved phosphorus concentrations were consistent with surface water sample results (CDOT, 2008).

3.8 Sand Particle Size Fractions

The above tables show the results for particle size fraction analysis for 2002-2005. Grain size results for 2007 are not available. CDOT grain size specifications for Class 7 "Aggregate Base Course" (or for aggregate to be used under pavement) are shown in one column on the left side. Classes 1 and 2 require coarser material, so Class 7 is the only appropriate reuse option. Class 7 requires a "Liquid Limit" of not more than 30 (CDOT, 1999, p. 882). Due to the low percentage of clay in sand samples, this is not a concern. Note that the specification sieve sizes differ slightly from the analyzed sizes in 2002 due to a miscommunication within the contract lab. Also, the smallest two sizes (silt and clay) are shown as percent of each NOT percent passing through a particular sieve size.

All size requirements were met for Class 7 aggregate base course, with the exception of the I-70 Eisenhower East sample in 2003 being slightly too fine. However, other area samples met the size criteria for Class 7 aggregate. In addition, if that sample was mixed with others in a stockpile the combination would meet size specifications.

The used traction sand sieve results for the three highway corridor areas are plotted in Figures 1-3. These data show generally coarser grained material in the Berthoud Pass area. The I-70 Vail Pass and Eisenhower Tunnel areas had similar grain size distributions. There was little difference from year to year within sample areas.

The vertical red line on the plots indicate the minimum size fraction acceptable for traction sand (0.85 mm). Data shows that at least 50 percent of the used traction sand material is coarse enough to meet CDOT specifications. Although much of the sand would meet the size requirements, the fines would need to be removed to meet specifications for reuse.

4.0 SUMMARY AND CONCLUSIONS

A total of 35 used traction sand samples have been collected and analyzed for chemical and physical characteristics from Colorado mountain highway shoulders and sediment basins over five years from 2002 to 2007 (except 2006). Three heavy sand use areas have been sampled including the I-70 Vail Pass area, I-70 Eisenhower Tunnel area, and US40 Berthoud Pass area. CO Highway 9 Hoosier Pass north was also sampled in 2002 and 2005.

None of the test parameter results show any discernable pattern in temporal year-to-year trends or in spatial distribution trends from corridor to corridor. The coefficient of variation was low for most chemical parameters, suggesting the used traction sand chemical composition is largely a reflection of the parent geologic material. Exceptions to this are oil and grease (which is likely from the roadway) and possibly total phosphorus.

Results show that metal concentrations are low and fall well below TCLP regulatory limits. The variation is also low for these samples, suggesting that samples reflect concentrations found in the sand source geologic material rather than from highway sources.

Oil and grease concentrations exceed the regulatory limit of 500 ppm in all samples, resulting in a solid waste classification. The source of the oil and grease is likely from the asphalt pavement (and roto-millings) used to pave the surface of roadways and shoulders, and from vehicles.

For purposes of traction sand reuse, these analyses show that greater than 50 percent of the used sand would meet size requirements and is not a hazardous waste. Although occasionally observed, large pieces of trash (paper cups, gloves, etc.) were not included in these samples, but small pieces of trash (such as cigarette butts, or broken plastic or glass) were included. Visual inspection of the sand suggests that about one or two percent of the total volume of sand is trash. This includes vehicle parts, such as fan belts, tires, and snow chains. Sieving to remove the larger trash items and the fines would be required to reuse traction sand.

For road base, the “R-value” for geotechnical stability for 2003 composite sample was 78, and for the 2004 composite sample was 75. Both values fall within specifications for Class 7 road base. The organic content generally is low enough to be acceptable for this type of reuse (Bob LaForce, pers. Communication, June 23, 2003).

For purposes of collection, disposal, and revegetation with plants, the used traction sand is neither hazardous nor excessively salty. The average pH is suitable to support plant growth. Any nutrient (phosphorus and nitrogen) content could also help to promote plant growth. Dissolved nutrients and trace metals should not pose an issue to local watersheds.

Traction sand reuse options should be considered further. Possible uses include aggregate for concrete, asphalt, or bricks; fill or capping material under road pavement; or alternative cap materials in landfills. At least 50 percent of the recovered material could be reused as traction sand. Such reuse would require sieving to remove fines and any extraneous trash that might compromise structural stability or cause other problems with reuse.

Future sampling and analysis should be conducted to determine the oil and grease concentration in asphalt paving material (bituminous) and asphalt roadway rotomillings. This roadway material ultimately becomes mixed with the used traction sand along the shoulders and in sediment collection basins. Total phosphorus concentrations should also be measured in traction sand product from local sources and in asphalt to determine potential sources.

CDOT Sand Sample Results 2002-2005, 2007

Station ID	Sample Area	Year Sampled	Milepost	Sample Source	Conductance (Mhos/cm)	pH	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Selenium
Reporting Limits	**Units (ppm)**				***0.002***		***1.0***	***1***	***0.5***	***1.0***	***2.0***	***0.8***	***0.03***	***1.30***
TCLP Reg Limits*							***5.0***	***100***	***1.0***	***5.0***		***5.0***	***0.20***	***1.00***
EJMT-E Road	I-70 Eisenhower Tunnel East	2002		Roadway	0.238	7.8	1.1	29	0.5 U	9.2	7.3	7.9	0.03 U	1.30 U
EJMT-E Road	I-70 Eisenhower Tunnel East*	2003		Roadway	0.130	8.3	1.7/2.2	180/210	0.5 U	21/26	20/19	12.0	0.03 U	1.30 U
EJMT-E Road	I-70 Eisenhower Tunnel East	July-2005	216-221	Roadway	0.006	7.4	2.2	77	0.7 B	12.0	15.0	15.4	0.04 U	0.50 U
EJMT-E Road	I-70 Eisenhower Tunnel East	June-2007	216-221	Roadway	0.007	7.4	2.5	77	0.5 U	14.0	21.0	15.1	0.04 U	0.19 B
EJMT-W Basin	I-70 Eisenhower Tunnel East	June-2007	216-221	Basins	0.003	7.5	1.5	33	0.5 U	9.0	9.0	13.1	0.04 U	0.13 B
EJMT-W Road	I-70 Eisenhower Tunnel West	2003		Roadway	0.057	8.2	1.0 U	42	0.5 U	14.0	7.5	12.0	0.03 U	1.30 U
EJMT-W Road	I-70 Eisenhower Tunnel West	2004		Roadway	0.230	7.7	2.8	50	0.5 U	14.0	15.0	8.6	0.03 U	1.30 U
EJMT-W Road	I-70 Eisenhower Tunnel West	May-2005	207-213	Roadway	0.004	8.0	2.6	68	0.5 U	16.0	16.0	11.7	0.05 U	0.50 U
EJMT-W Road	I-70 Eisenhower Tunnel West	June-2007	207-213	Roadway	0.005	7.6	2.6	80	0.5 U	20.0	17.0	13.5	0.04 U	0.22 B
EJMT-W Basin	I-70 Eisenhower Tunnel West	July-2005	211-213	Basins	0.002	7.8	2.0	49	0.5 B	12.0	11.0	9.2	0.05 U	0.50 U
EJMT-W Basin	I-70 Eisenhower Tunnel West	June-2007		Basins	0.006	7.8	2.1	61	0.5 U	11.0	11.0	9.8	0.04 U	0.19 B
Vail-E Road	I-70 Vail Pass East	2002	195-201	Roadway	0.080	8.5	2.2	47	0.5 U	9.6	8.0	17.1	0.03 U	1.30 U
Vail-E Road	I-70 Vail Pass East	2003	190-195	Roadway	0.110	9.2	1.7	53	0.5 U	14.0	10.0	8.8	0.03 U	1.30 U
Vail-E Road	I-70 Vail Pass East	2004		Roadway	0.310	8.4	1.4	59	0.5 U	13.0	10.0	7.5	0.03 U	1.30 U
Vail-W Road	I-70 Vail Pass West	2003	180-190	Roadway	0.070	9.1	1.0 U	130	0.5 U	19.0	8.3	9.7	0.03 U	1.30 U
Vail-W Road	I-70 Vail Pass West	2004		Roadway	0.220	8.6	1.3	70	0.5 U	15.0	11.0	8.3	0.03 U	1.30 U
Vail-W Road	I-70 Vail Pass West	May-2005	182-190	Roadway	0.005	7.9	2.6	81	0.5 U	22.0	16.0	10.0	0.05 U	0.50 U
Vail-W Road	I-70 Vail Pass West	June-2007	180-190	Roadway	0.014	7.6	4.1	95	0.5 U	21.0	20.0	13.6	0.03 U	0.30 B
Vail-W Basin	I-70 Vail Pass West	July-2005	182-189	Basins	0.002	8.2	3.2	76	0.6 U	15.0	22.0	26.8	0.04 U	0.50 U
Vail-W Basin	I-70 Vail Pass West	June-2007		Basins	0.007	7.7	2.9	76	0.5 U	20.0	23.0	12.7	0.19 B	0.25 B
Berthoud-E Road	US-40 Empire-Berthoud Falls	2002		Roadway	0.120	9.2	1.0	33	0.5 U	4.8	7.0	7.4	0.03 U	1.30 U
Berthoud-E Road	US 40 Empire-Berthoud Falls*	2004		Roadway	0.044/0.039	8.1	1.3/1.3	36/39	0.5 U	8.6/9.7	9.8/14	13/24	0.03 U	1.30 U
Berthoud-E Road	US-40 Berthoud Pass East	2002		Roadway	0.055	9.2	1.0	33	0.5 U	4.8	7.0	7.4	0.03 U	1.30 U
Berthoud-E Road	US-40 Berthoud Pass East	2003		Roadway	0.010	9.1	1.0 U	40	0.5 U	9.3	7.8	12.0	0.03 U	1.30 U
Berthoud-E Road	US-40 Berthoud Pass East	May-2005	243-247	Roadway	0.002	7.9	2.2	32	1.0 U	8.0	11.0	7.1	0.05 U	0.50 U
Berthoud-E Road	US-40 Berthoud Pass East	June-2007	243-247	Roadway	0.001	8.2	1.9	37	0.5 U	10.0	10.0	9.0	0.04 U	0.18 B
Berthoud-E Basin	US-40 Berthoud Pass East	June-2007		Basins	0.000	7.7	1.7	53	0.5 U	12.0	21.0	13.3	0.04 U	0.24 B
Berthoud-W Road	US-40 Berthoud Pass West	2002		Roadway	0.010	9.0	1.0 U	20	0.5 U	4.5	2.1	3.4	0.03 U	1.30 U
Berthoud-W Road	US-40 Berthoud Pass West	2003		Roadway	0.024	9.2	1.0 U	28	0.5 U	7.8	5.4	12.0	0.03 U	1.30 U
Berthoud-W Road	US-40 Berthoud Pass West	July-2005	237-243	Roadway	0.002	7.7	2.4	45	0.5 U	10.0	13.0	14.4	0.04 U	0.50 U
Berthoud-W Road	US-40 Berthoud Pass West	June-2007	236-240	Roadway	0.001	8.2	2.2	36	0.5 U	11.0	18.0	7.8	0.04 U	0.16 B
Berthoud-W Basin	US-40 Berthoud Pass West	June-2007		Basins	0.001	7.9	1.8	35	0.5 U	11.0	11.0	7.5	0.04 U	0.12 B
	CO-9 Hoosier Pass North	2002	76-82	Roadway	0.054	9.2	1.0 U	36	0.5 U	6.6	8.1	6.5	0.03 U	1.30 U
	CO-9 Hoosier Pass North	July-2005	76-82	Roadway	0.012	7.7	2.3	59	0.9 B	15.0	13.0	16.1	0.05 U	0.50 U
	Vail Sand Berm	2003	179	Berm	0.052	8.6	1.9	51	0.5 U	11.0	N/A	14.0	0.03 U	1.30 U
Summary Statistics														
Number of Samples					34	35	33	33	35	33	32	34	35	35
Mean					0.054	8.2	1.9	54	0.5 U	12.3	12.3	11.2	0.04 U	0.80 U
Maximum					0.310	9.2	4.1	130	1.0 U	22.0	23.0	26.8	0.19	1.30 U
Minimum					0.000	7.4	1.0 U	20	0.5 U	4.5	2.1	3.4	0.03 U	0.12
Standard Deviation					0.082	0.6	0.8	23	N/C	4.6	5.3	4.2	N/C	N/C
Coeff. Variation					1.50	0.07	0.40	0.43	N/C	0.38	0.43	0.38	N/C	N/C

* Two numbers shown are for duplicate analyses of samples from the same location in order to assess analytical variation.

Total phosphorus was reanalyzed in 2003; 2005-2007 TP data converted to mg/kg from percent solids.

**TCLP regulated levels designate a waste as “hazardous” if the leachate from the solid waste meets or exceeds the listed concentrations; if the total metal in the solid is less than 20 times the concentration the solid is not “hazardous” for that metal (USEPA. 1996).

U = Not Detected at the indicated Reporting Limit; **N/A** = Not Analyzed; **B** = Detected at a concentration between the MDL and PQL; **Q** = Sample concentration was too high originally and was diluted and reanalyzed;**N/C** = Not Computed due to non detects.

CDOT Sand Sample Results 2002-2005, 2007

Station ID	Sample Area	Year Sampled	Silver	Zinc	Total Organic Carbon	Oil and Grease	Petroleum Hydrocarbon	Phosphorus Total	Phosphorus Dissolved	Diss. NH3	NO3+NO2 Dissolved	DIN	Nitrogen Dissolved
Reporting Limits	**Units (ppm)**		***1.0***	***2***	***0.01***	***500***	***3***	***5.0-25***	***0.003***	***0.01***	***0.01***	***0.02***	***0.02***
TCLP Reg Limits*			***5.0***										
EJMT-E Road	I-70 Eisenhower Tunnel East	2002	1.0 U	37	N/A	2100	N/A	8.6	0.018	0.13	0.07	0.20	N/A
EJMT-E Road	I-70 Eisenhower Tunnel East*	2003	1.0 U	45/54	2.4%	720	N/A	380 Q	0.053	0.01	0.04	0.05	0.28
EJMT-E Road	I-70 Eisenhower Tunnel East	July-2005	1.0 U	81	1.3%	6200	N/A	351	N/A	N/A	N/A	N/A	N/A
EJMT-E Road	I-70 Eisenhower Tunnel East	June-2007	1.0 U	89	1.4%	3500	170	947	N/A	N/A	N/A	N/A	N/A
EJMT-W Basin	I-70 Eisenhower Tunnel East	June-2007	1.0 U	49	0.7%	810	50	964	N/A	N/A	N/A	N/A	N/A
EJMT-W Road	I-70 Eisenhower Tunnel West	2003	1.0 U	37	1.1%	1500	N/A	N/A	0.041	<0.01	0.03	0.04	0.28
EJMT-W Road	I-70 Eisenhower Tunnel West	2004	1.0 U	50	1.0%	3000	N/A	<5	N/A	N/A	N/A	N/A	N/A
EJMT-W Road	I-70 Eisenhower Tunnel West	May-2005	0.5 U	92	1.5%	2900	N/A	401	N/A	N/A	N/A	N/A	N/A
EJMT-W Road	I-70 Eisenhower Tunnel West	June-2007	1.0 U	72	1.7%	2400	150	896	N/A	N/A	N/A	N/A	N/A
EJMT-W Basin	I-70 Eisenhower Tunnel West	July-2005	1.0 U	64	0.4% B	1700 B	N/A	278	N/A	N/A	N/A	N/A	N/A
EJMT-W Basin	I-70 Eisenhower Tunnel West	June-2007	1.0 U	68	0.8%	1500	80	1263	N/A	N/A	N/A	N/A	N/A
Vail-E Road	I-70 Vail Pass East	2002	1.0 U	92	N/A	1150	N/A	305	0.068	0.07	0.13	0.19	N/A
Vail-E Road	I-70 Vail Pass East	2003	1.0 U	42	1.0%	1700	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vail-E Road	I-70 Vail Pass East	2004	1.0 U	49	1.1%	2200	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vail-W Road	I-70 Vail Pass West	2003	1.0 U	41	0.9%	2100	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vail-W Road	I-70 Vail Pass West	2004	1.0 U	51	1.0%	2700	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vail-W Road	I-70 Vail Pass West	May-2005	0.5 U	88	1.2%	3000	N/A	596	N/A	N/A	N/A	N/A	N/A
Vail-W Road	I-70 Vail Pass West	June-2007	1.0 U	104	1.4%	2600	138	1026	N/A	N/A	N/A	N/A	N/A
Vail-W Basin	I-70 Vail Pass West	July-2005	1.0 U	105	0.5%	1700	N/A	276	N/A	N/A	N/A	N/A	N/A
Vail-W Basin	I-70 Vail Pass West	June-2007	1.0 U	74	0.7%	1400	31	540	N/A	N/A	N/A	N/A	N/A
Berthoud-E Road	US-40 Empire-Berthoud Falls	2002	1.0 U	32	N/A	1660	N/A	278 Q	0.068	0.12	0.34	0.46	N/A
Berthoud-E Road	US 40 Empire-Berthoud Falls*	2004	1.0 U	41/47	0.69/0.63	1600	N/A	16 / 95	0.007	0.62	0.22	N/A	N/A
Berthoud-E Road	US-40 Berthoud Pass East	2002	1.0 U	32	N/A	3290	N/A	221 Q	0.077	0.08	0.24	0.33	N/A
Berthoud-E Road	US-40 Berthoud Pass East	2003	1.0 U	90	0.6%	1400	N/A	280 Q	0.031	<0.01	0.04	0.05	0.28
Berthoud-E Road	US-40 Berthoud Pass East	May-2005	0.5 U	51	0.5%	1200 B	N/A	148	N/A	N/A	N/A	N/A	N/A
Berthoud-E Road	US-40 Berthoud Pass East	June-2007	1.0 U	47	0.6%	880	103	576	N/A	N/A	N/A	N/A	N/A
Berthoud-E Basin	US-40 Berthoud Pass East	June-2007	1.0 U	64	0.6%	820	77	718	N/A	N/A	N/A	N/A	N/A
Berthoud-W Road	US-40 Berthoud Pass West	2002	1.0 U	12	N/A	500 U	N/A	25.8Q	N/A	N/A	N/A	N/A	N/A
Berthoud-W Road	US-40 Berthoud Pass West	2003	1.0 U	22	0.5%	520	N/A	310 Q	0.039	<0.01	0.02	0.03	0.26
Berthoud-W Road	US-40 Berthoud Pass West	July-2005	1.0 U	60	0.5%	1000 B	N/A	255	N/A	N/A	N/A	N/A	N/A
Berthoud-W Road	US-40 Berthoud Pass West	June-2007	1.0 U	52	0.7%	910	78	619	N/A	N/A	N/A	N/A	N/A
Berthoud-W Basin	US-40 Berthoud Pass West	June-2007	1.0 U	50	0.6%	550	50	323	N/A	N/A	N/A	N/A	N/A
	CO-9 Hoosier Pass North	2002	1.0 U	30	N/A	754	N/A	223	0.053	0.05	0.07	0.12	N/A
	CO-9 Hoosier Pass North	July-2005	1.0 U	63	0.6%	1400	N/A	291	N/A	N/A	N/A	N/A	N/A
	Vail Sand Berm	2003	1.0 U	N/A	1.3%	2500	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Summary Statistics													
Number of Samples			35	32	28	35		26					
Mean			1.0 U	59	1.0%	1825		499					
Maximum			1.0 U	105	2.4%	6200		1263					
Minimum			0.5 U	12	0.4%	500		148					
Standard Deviation			N/C	24	0.5%	1139		306					
Coeff. Variation			N/C	0.41	0.48	0.62		0.61					

* Two numbers shown are for duplicate analyses of samples from the

**TCLP regulated levels designate a waste as “hazardous” if the leach

U = Not Detected at the indicated Reporting Limit; **N/A** = Not Analyzed

CDOT Sand Sample Summary Statistics

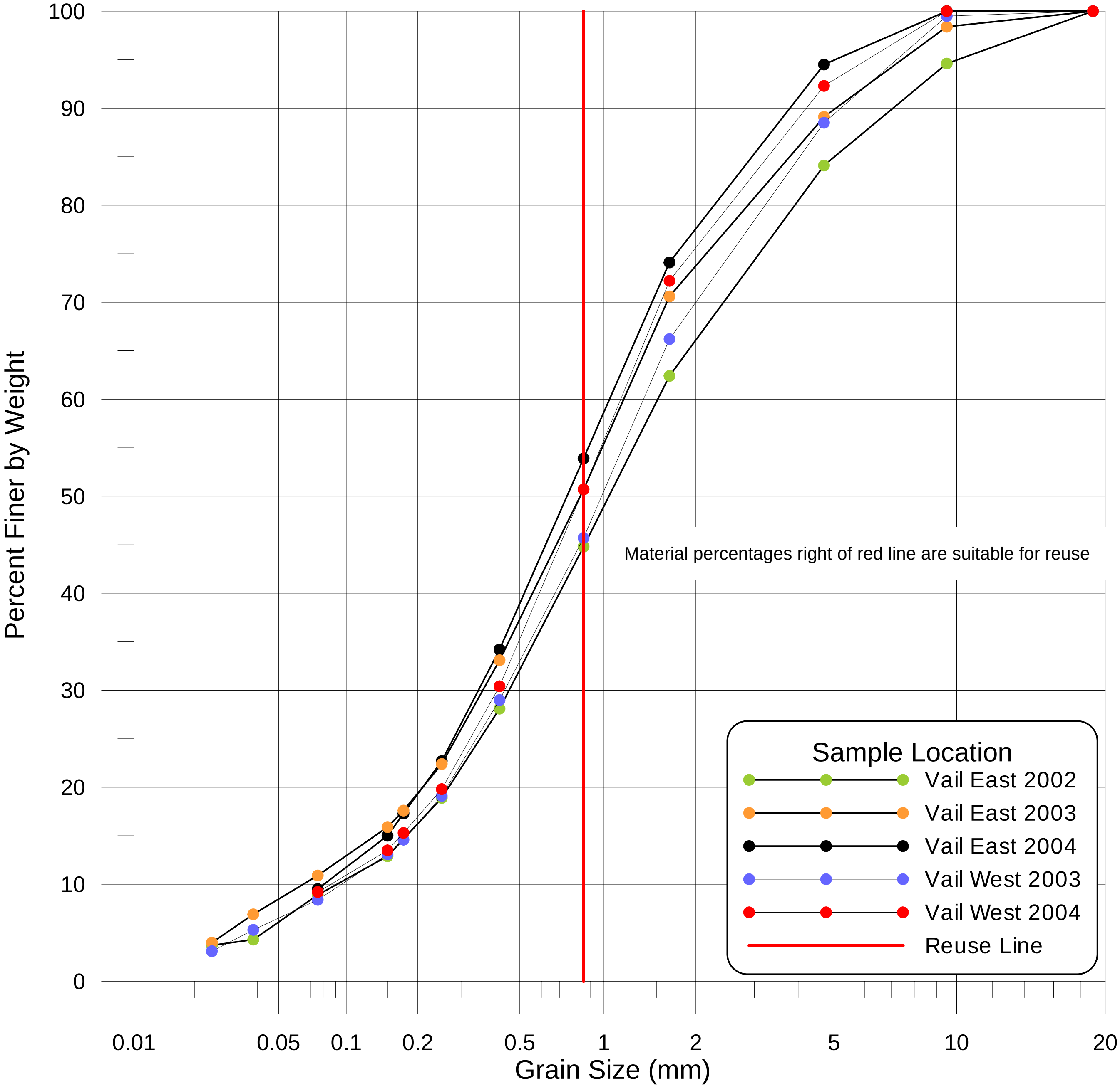
2002-2005 and 2007 Sample Data

	Conductance (Mhos/cm)	pH	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Silver	Zinc	Total Organic Carbon	Oil and Grease	Phosphorus Total
Reporting Limits	***0.002***		***1.0***	***1***	***0.5***	***1.0***	***2.0***	***0.8***	***0.03***	***1.30***	***1.0***	***2***	***0.01***	***500***	***5.0-25***
TCLP Reg Limits**			***5.0***	***100***	***1.0***	***5.0***		***5.0***	***0.20***	***1.00***	***5.0***				
Summary Statistics Roadway															
Number of Samples	24	25	23	23	25	23	23	24	25	25	25	23	19	25	16
Mean	0.071	8.3	1.9	55	0.5 U	12.3	11.5	10.5	0.03 U	0.92 U	0.9 U	58	1.1%	2029	474
Maximum	0.310	9.2	4.1	130	1.0 U	22.0	21.0	17.1	0.05	1.30 U	1.0 U	104	2.4%	6200	1026
Minimum	0.001	7.4	1.0 U	20	0.5 U	4.5	2.1	3.4	0.03 U	0.16	0.5 U	12	0.5%	500	148
Standard Deviation	0.092	0.6	0.8	26	N/C	5.0	5.0	3.3	N/C	N/C	N/C	26	0.5%	1246	275
Coeff. Variation	1.29	0.07	0.44	0.48	N/C	0.41	0.43	0.32	N/C	N/C	N/C	0.45	0.45	0.61	0.58
Summary Statistics Basins															
Number of Samples	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Mean	0.003	7.8	2.2	55	0.5 U	12.9	15.4	13.2	0.06 U	0.28 U	1.0 U	68	0.6%	1211	623
Maximum	0.007	8.2	3.2	76	0.6 U	20.0	23.0	26.8	0.19	0.50 U	1.0 U	105	0.8%	1700	1263
Minimum	0.000	7.5	1.5 U	33	0.5 U	9.0	9.0	7.5	0.04 U	0.12	1.0 U	49	0.4%	550	276
Standard Deviation	0.003	0.2	0.6	18	N/C	3.6	6.2	6.4	N/C	N/C	N/C	19	0.1%	474	381
Coeff. Variation	0.87	0.03	0.29	0.33	N/C	0.28	0.40	0.49	N/C	N/C	N/C	0.28	0.22	0.39	0.61
Summary Statistics Combined															
Number of Samples	34	35	33	33	35	33	32	34	35	35	35	32	28	35	25
Mean	0.054	8.2	1.9	54	0.5 U	12.3	12.3	11.2	0.04 U	0.80 U	1.0 U	59	1.0%	1825	499
Maximum	0.310	9.2	4.1	130	1.0 U	22.0	23.0	26.8	0.19	1.30 U	1.0 U	105	2.4%	6200	1263
Minimum	0.000	7.4	1.0 U	20	0.5 U	4.5	2.1	3.4	0.03 U	0.12	0.5 U	12	0.4%	500	148
Standard Deviation	0.082	0.6	0.8	23	N/C	4.6	5.3	4.2	N/C	N/C	N/C	24	0.5%	1139	306
Coeff. Variation	1.50	0.07	0.40	0.43	N/C	0.38	0.43	0.38	N/C	N/C	N/C	0.41	0.48	0.62	0.61

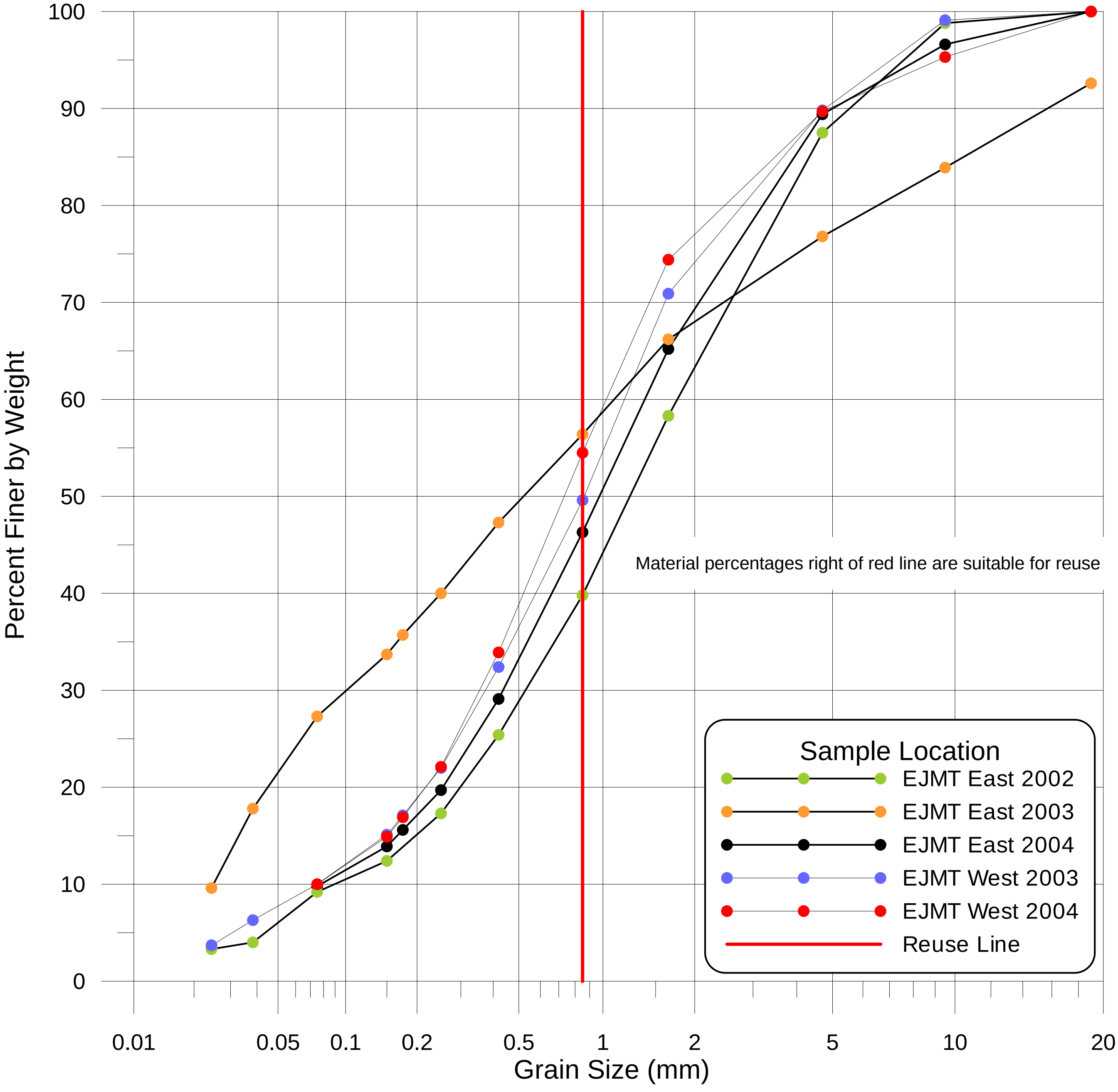
**TCLP regulated levels designate a waste as “hazardous” if the leachate from the solid waste meets or exceeds the listed concentrations; if the total metal in the solid is less than 20 times the concentration the solid is not “hazardous” for that metal.

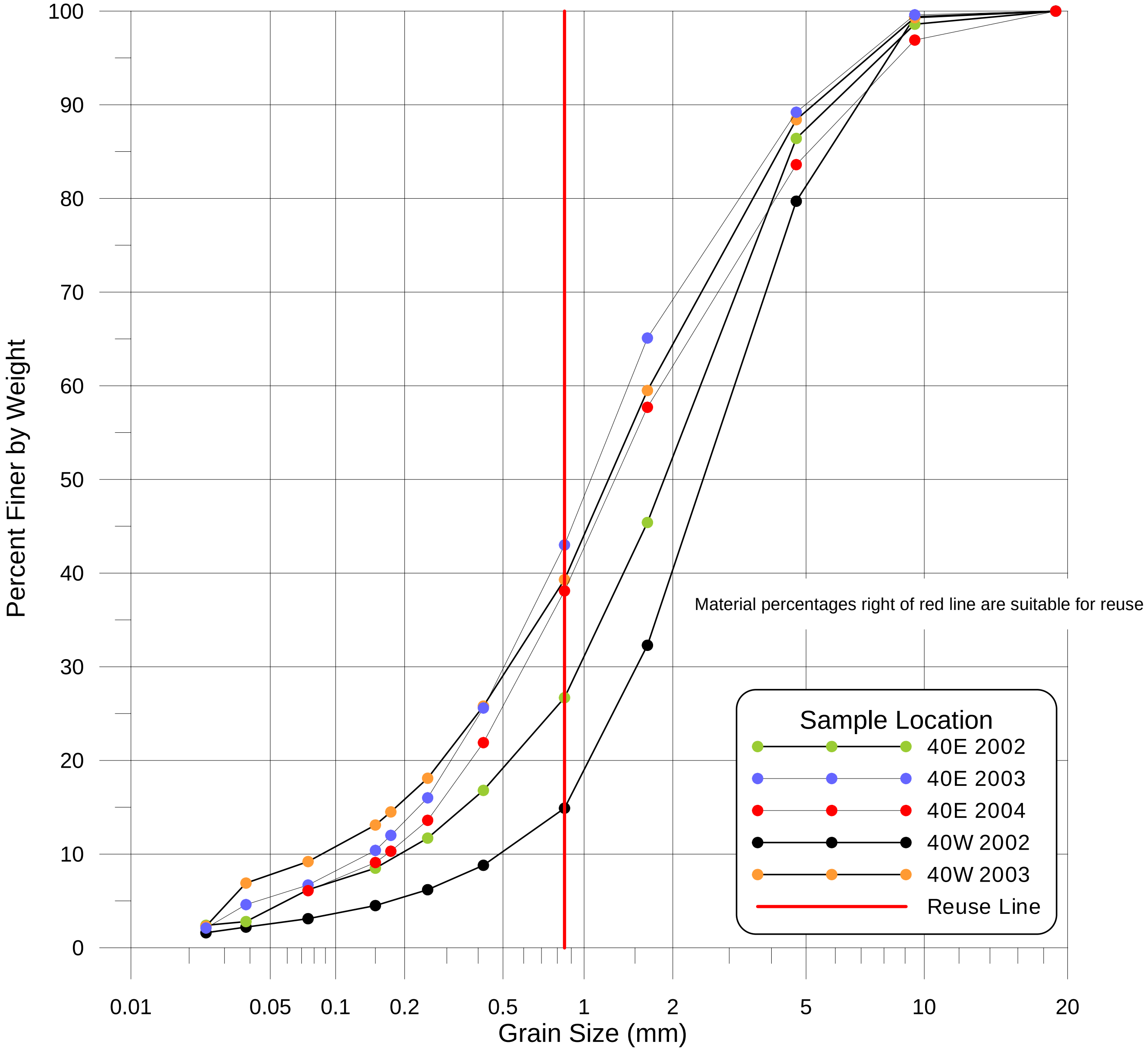
U = Not Detected at the indicated Reporting Limit; **N/C** = Not Computed due to non-detects

Vail Pass Area I-70 Milepost 180-200
Used Traction Sand Grain Size



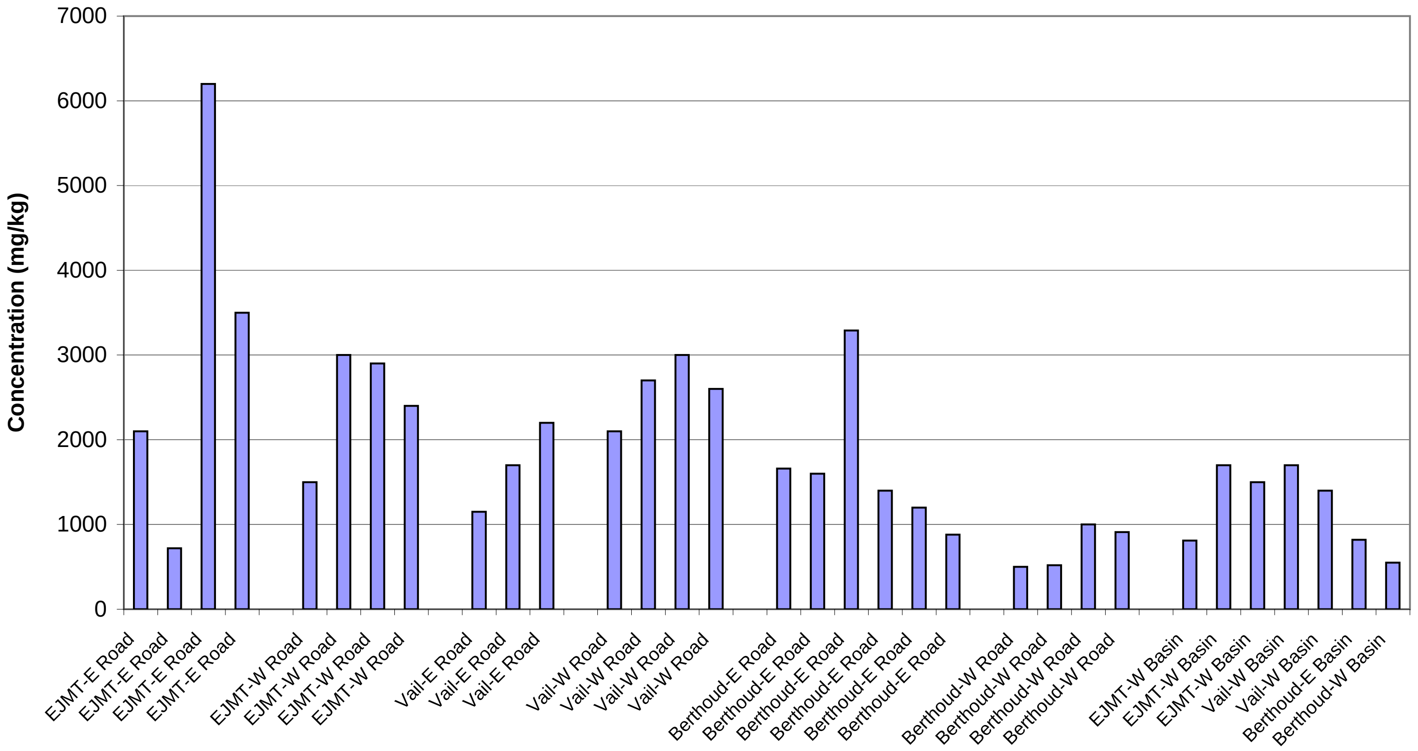
EJMT Area I-70 Milepost 207-221
Used Traction Sand Grain Size



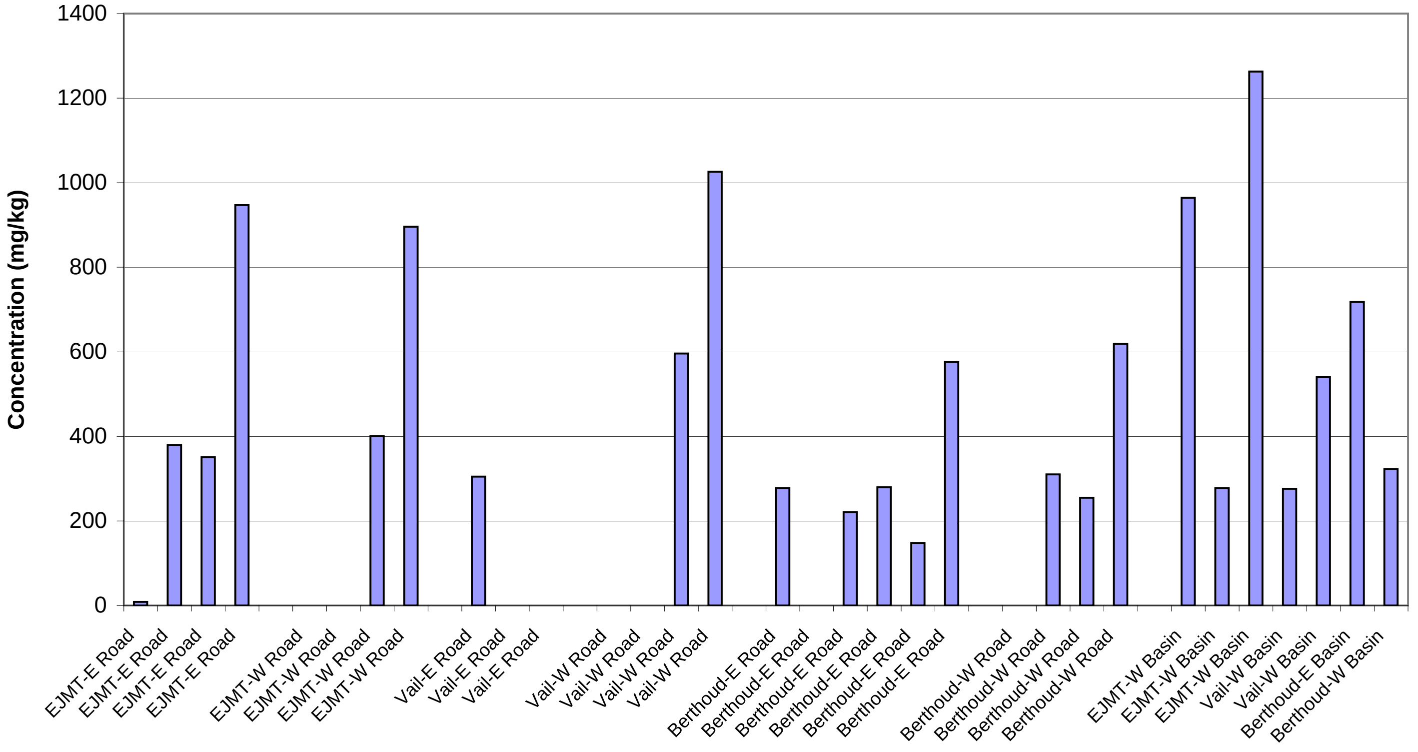


Berthoud Pass Area US40 Milepost 236-247
Used Traction Sand Grain Size

Material percentages right of red line are suitable for reuse



Oil and Grease
CDOT Used Traction Sand 2002-2007



Total Phosphorus
CDOT Used Traction Sand 2002-2007

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Huyck, Holly L.O., 2003d, Sand Sample Locations and Field Notes for May 19-20, 2003: internal report, – p.

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Appendix A
Traction Sand Sources

Roadway Area	2002	2003	2004	2005	2007
US 40, Empire to Berthoud Falls	Ready Mix	Ready Mix	Everest		
US 40, Berthoud Falls to Berthoud Pass East	Ready Mix	Ready Mix	Everest		
US 40. Berthoud Pass West to Fraser River**	Ready Mix	Ready Mix	Everest		
I-70, Georgetown to Empire exit	Ready Mix	Everest	Everest		
I-70, Eisenhower Pass East	Ready Mix	Everest	Everest		
I-70, Straight Creek, Eisenhower Pass West to Silverthorne exit	Everest	Everest	Everest		
I-70, Silverthorne exit to Officers Gulch	Everest	Everest	Everest		
I-70, Vail Pass East, Officers Gulch to Vail Pass	Everest	Everest	Everest		
I-70, Black Gore Creek, Vail Pass to East Vail exit	Everest	Everest	Everest		
Vail Sand Berm	mixed	mixed	mixed		
SH 9, Hoosier Pass North	ACA	ACA	Willets		
SH 9, Hoosier Pass South			Willets		

Appendix B
Sand Disposal Documentation

After discussing the used sand disposal issue with Pat Martinek (CDOT liaison to CDPHE) and Glenn Mallory (head of the Solid Waste program at CDPHE), Ms. Julie Cotter responded regarding what to do with sands containing the above oil and grease (phone conversation, January 7, 2003). As long as CDOT is moving the sand to a controlled site (e.g. not to be gardened or dug for utilities), piles the material, and plants native species on it, the sand generally can be handled in this fashion. (Plants may actually use the hydrocarbons for nutrients.) However, for each new batch of sand or new site, the sand should be sampled for several constituents (including oil and grease), and the analyses should be sent to Pat Martinek for her information. *Note: The existing analyses do not cover future sand sources, and any new use must be pre-approved by Ms. Martinek before implementing a disposal plan (per phone conversation with Pat Martinek, January 7, 2003).*

In addition, due to the oil and grease contents, the Solid Waste section of CDPHE requires that samples be taken from future sand sources, and both results and a disposal plan be submitted to Ms. Martinek (CDOT liaison, 303-692-3446) prior to implementation of any plan. Any proposed disposal site should be in an area where future disturbance of the material (e.g., by digging for utilities or planting a garden) is unlikely.

APPENDIX D

Colorado Soil Evaluation Values

Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division
Table 1 Colorado Soil Evaluation Values (CSEV) – December 2007

Class	Analyte (CDPHE Preferred Name)	CAS No.	Residential		Worker [4]		Groundwater Protection Level		Leachate Reference Concentration		Water Standard	
			[mg/kg]	Notes	[mg/kg]	Notes	[mg/kg]	Notes	[mg/L]	Notes	[mg/L]	Notes
Inorganics	Aluminum	7429-90-5	75000	nc	900000	nc	NA		110		5	1,3
	Antimony	7440-36-0	31	nc	410	nc	NA		0.13		0.006	1
	Arsenic	7440-38-2	0.39	10,c	1.6	10,c	NA		1.1		0.05	1
	Barium	7440-39-3	15000	nc	160000	nc	NA		44		2	1
	Beryllium	7440-41-7	150	nc	1900	c	NA		0.088		0.004	1
	Cadmium and compounds	7440-43-9	70	nc	810	nc	NA		0.11		0.005	1
	Chromium(III)	16065-83-1	120000	nc	1500000	nc	NA		2.2	6	0.1	1,6
	Chromium(VI) particulates	18540-29-9	23	c	53	c	NA		0.46		0.021	2
	Cobalt	7440-48-4	700	c	1600	c	NA		1.1		0.05	1
	Copper and compounds	7440-50-8	3100	nc	41000	nc	NA		4.4		0.2	1,3
	Iron	7439-89-6	23000	nc	310000	nc	NA		6.6		0.3	1
	Lead (inorganic)	7439-92-1	400	11,nc	800	11,nc	NA		1.1		0.05	1
	Lead (tetraethyl)	78-00-2	0.0078	nc	0.1	nc	NA		0.000015		0.0000007	2
	Manganese	7439-96-5	1500	nc	16000	nc	NA		1.1		0.05	1
	Mercury compounds (i.e., HgCl)	7487-94-7	23	nc	310	nc	NA		0.044		0.002	1
	Nickel (soluble salts)	7440-02-0	1600	nc	20000	nc	NA		2.2		0.1	1
	Selenium	7782-49-2	390	nc	5100	nc	NA		0.44		0.02	1,3
	Silver	7440-22-4	390	nc	5100	nc	NA		1.1		0.05	1
	Thallium (sulfate etc.)	7440-28-0	5.5	nc	72	nc	NA		0.044		0.002	1
	Vanadium	7440-62-2	78	nc	1000	nc	NA		2.2		0.1	1,3
	Zinc	7440-66-6	23000	nc	310000	nc	NA		44		2	1,3
VOCs	Acenaphthene	83-32-9	1000	5,9,nc	1000	5,9,nc	1000	5	NA		0.42	1
	Acetone	67-64-1	1000	5,nc	1000	5,nc	Pending		NA		6.3	2
	Acetophenone	98-86-2	1000	5,nc	1000	5,nc	Pending		NA		0.7	2
	Anthracene	120-12-7	1000	5,9,nc	1000	5,9,nc	1000	5	NA		2.1	1
	Benzene	71-43-2	1	c	2.3	c	0.17		NA		0.005	1
	Bis(2-chloroisopropyl)ether	108-60-1	8.3	9,c	34	9,c	Pending		NA		0.005	2
	Bromobenzene	108-86-1	400	9,nc	1000	5,9,nc	Pending		NA		0.14	2
	Bromodichloromethane	75-27-4	0.63	9,c	1.5	9,c	0.007		NA		0.00056	1
	Bromomethane	74-83-9	3.7	nc	15	nc	0.16		NA		0.01	2
	2-Butanone	78-93-3	1000	5,9,nc	1000	5,9,nc	18		NA		4.2	2
	n-Butylbenzene	104-51-8	1000	5,nc	1000	5,nc	240		NA		0.28	2
	sec-Butylbenzene	135-98-8	1000	5,nc	1000	5,nc	230		NA		0.28	2
	tert-Butylbenzene	98-06-6	1000	5,nc	1000	5,nc	230		NA		0.28	2
	Carbon disulfide	75-15-0	280	nc	1000	5,nc	1000	5	NA		0.7	2
	Carbon tetrachloride	56-23-5	0.18	c	0.41	c	0.92		NA		0.00027	1
	Chlorobenzene	108-90-7	Pending		Pending		5.3		NA		0.1	1
	Chloroethane	75-00-3	2.1	c	4.8	c	Pending		NA		0.12	2
	Chloroform	67-66-3	Pending		Pending		Pending		NA		0.0035	1
	Chloromethane	74-87-3	47	nc	190	nc	Pending		NA		0.18	2
	beta-Chloronaphthalene	91-58-7	1000	5,9,nc	1000	5,9,nc	Pending		NA		0.56	1
	2-Chlorophenol	95-57-8	360	9,nc	1000	5,9,nc	Pending		NA		0.035	1
	Cumene	98-82-8	1000	5,9,nc	1000	5,9,nc	700		NA		0.7	2
	Dibenzofuran	132-64-9	140	9,nc	1000	5,9,nc	Pending		NA		0.014	2
	1,2-Dibromo-3-chloropropane	96-12-8	0.2	7,c	3.6	7,c	0.002		NA		0.0002	1
	Dibromochloromethane	124-48-1	0.87	9,c	2.1	9,c	Pending		NA		0.014	1
	1,2-Dibromoethane	106-93-4	0.04	9,c	0.1	9,c	Pending		NA		0.00000041	1
	1,2-Dichlorobenzene	95-50-1	630	9,nc	1000	5,9,nc	57		NA		0.6	1
	1,3-Dichlorobenzene	541-73-1	Pending		Pending		Pending		NA		0.094	1
	1,4-Dichlorobenzene	106-46-7	3	9,c	7.2	9,c	7.8		NA		0.075	1
	Dichlorodifluoromethane	75-71-8	79	nc	310	nc	390		NA		1.4	2
	1,1-Dichloroethane	75-34-3	480	nc	1000	5,nc	3.9		NA		0.14	2
	1,2-Dichloroethane	107-06-2	0.33	9,c	0.78	9,c	0.0036		NA		0.00038	1
	cis-1,2-Dichloroethene	156-59-2	42	nc	170	nc	1.3		NA		0.07	1
	trans-1,2-Dichloroethene	156-60-5	60	nc	240	nc	5.4		NA		0.1	1
	1,1-Dichloroethylene	75-35-4	2.5	8,nc	10	8,nc	12		NA		0.007	1
	1,2-Dichloropropane	78-87-5	0.4	9,c	0.93	9,c	0.0087		NA		0.00052	1
	1,3-Dichloropropene	542-75-6	2	9,c	5.4	9,c	Pending		NA		0.0035	2
	Ethyl ether	60-29-7	880	nc	1000	5,nc	Pending		NA		1.4	2
	Ethyl methacrylate	97-63-2	1000	5,9,nc	1000	5,9,nc	Pending		NA		0.63	2
	Ethylacetate	141-78-6	1000	5,9,nc	1000	5,9,nc	Pending		NA		6.3	2
	Ethylbenzene	100-41-4	1000	5,9,nc	1000	5,9,nc	100		NA		0.7	1
	Fluorene	86-73-7	1000	5,9,nc	1000	5,9,nc	1000	5	NA		0.28	1
	4-Methyl-2-pentanone	108-10-1	1000	5,9,nc	1000	5,9,nc	3.3		NA		0.56	2
	Methylene chloride	75-09-2	9	c	22	c	0.06		NA		0.0047	1
	2-Methylnaphthalene	91-57-6	290	9,nc	1000	5,9,nc	Pending		NA		0.028	2
	Naphthalene	91-20-3	1000	5,9,nc	1000	5,9,nc	23		NA		0.14	1
	Nitrobenzene	98-95-3	22	9,nc	150	9,nc	Pending		NA		0.0035	1
	n-Propylbenzene	103-65-1	1000	5,nc	1000	5,nc	Pending		NA		0.28	2
	Styrene	100-42-5	1000	5,9,nc	1000	5,9,nc	14		NA		0.1	1
	1,1,1,2-Tetrachloroethane	630-20-6	1.7	9,c	4	9,c	Pending		NA		0.021	2
	1,1,2,2-Tetrachloroethane	79-34-5	0.42	9,c	1	9,c	0.0024		NA		0.00018	1
	Tetrachloroethylene	127-18-4	0.45	8,c	1.3	8,c	1.9		NA		0.005	1
	Toluene	108-88-3	1000	5,9,nc	1000	5,9,nc	85		NA		1	1
	1,2,4-Trichlorobenzene	120-82-1	37	9,nc	150	9,nc	13		NA		0.07	1
	1,1,1-Trichloroethane	71-55-6	1000	5,nc	1000	5,nc	62		NA		0.2	1
	1,1,2-Trichloroethane	79-00-5	0.85	9,c	2	9,c	Pending		NA		0.0028	1
	Trichloroethylene	79-01-6	0.039	8,c	0.09	8,c	0.68		NA		0.005	1
	Trichlorofluoromethane	75-69-4	280	nc	1000	5,nc	1000	5	NA		2.1	2
	1,2,3-Trichloropropane	96-18-4	0.047	9,c	0.11	9,c	Pending		NA		0.00018	2
	Trichlorotrifluoroethane	76-13-1	1000	5,nc	1000	5,nc	1000	5	NA		210	2

Class	Analyte (CDPHE Preferred Name)	CAS No.	Residential		Worker [4]		Groundwater Protection Level		Leachate Reference Concentration		Water Standard	
			[mg/kg]	Notes	[mg/kg]	Notes	[mg/kg]	Notes	[mg/L]	Notes	[mg/L]	Notes
VOCs	1,2,4-Trimethylbenzene	95-63-6	22	9,nc	85	9,nc	71		NA		0.35	2
	1,3,5-Trimethylbenzene	108-67-8	19	9,nc	74	9,nc	110		NA		0.35	2
	Vinyl acetate	108-05-4	390	9,nc	1000	5,9,nc	51		NA		7	2
	Vinyl chloride	75-01-4	0.09	7,c	4	7,c	0.11		NA		0.000023	1
	Xylenes (total)	1330-20-7	280	9,nc	1000	5,9,nc	175		NA		1.4	1
SVOCs	Benz[a]anthracene	56-55-3	0.22	7,c	3.9	7,c	1000	5	NA		0.0000048	1
	Benzo[a]pyrene	50-32-8	0.022	7,c	0.39	7,c	1000	5	NA		0.0000048	1
	Benzo[b]fluoranthene	205-99-2	0.22	7,c	3.9	7,c	1000	5	NA		0.0000048	1
	Benzo[k]fluoranthene	207-08-9	2.2	7,c	39	7,c	1000	5	NA		0.0000048	1
	Benzoic acid at pH 6.8	65-85-0	1000	5,nc	1000	5,nc	110		NA		28	2
	Bis-2-ethylhexyl phthalate	117-81-7	35	c	120	c	1000	5	NA		0.0025	1
	Bromoform	75-25-2	20	c	52	c	0.048		NA		0.004	1
	Butylbenzylphthalate	85-68-7	1000	5,nc	1000	5,nc	1000	5	NA		1.4	1
	Carbazole	86-74-8	24	c	86	c	Pending		NA		0.018	2
	Chlordane	57-74-9	1.6	c	6.5	c	1000	5	NA		0.0001	1
	Chrysene	218-01-9	22	7,c	390	7,c	1000	5	NA		0.0000048	1
	Cyclohexanone	108-94-1	1000	5,nc	1000	5,nc	Pending		NA		35	2
	Dibenzo[a,h]anthracene	53-70-3	0.022	7,c	0.39	7,c	1000	5	NA		0.0000048	1
	3,3'-Dichlorobenzidine	91-94-1	1.1	c	3.8	c	Pending		NA		0.000078	1
	2,4-Dichlorophenol	120-83-2	180	nc	1000	5,nc	0.33		NA		0.021	1
	Diethylphthalate	84-66-2	1000	5,nc	1000	5,nc	140		NA		5.6	1
	a,a-Dimethylphenethylamine	122-09-8	61	nc	620	nc	Pending		NA		0.007	2
	2,4-Dimethylphenol	105-67-9	1000	5,nc	1000	5,nc	2.7		NA		0.14	1
	Dimethylphthalate	131-11-3	1000	5,nc	1000	5,nc	760		NA		70	2
	di-n-Butyl phthalate	84-74-2	1000	5,nc	1000	5,nc	1000	5	NA		0.7	1
	1,2-Dinitrobenzene	528-29-0	6.1	nc	62	nc	Pending		NA		0.0007	2
	1,4-Dinitrobenzene	100-25-4	6.1	nc	62	nc	Pending		NA		0.0007	2
	2,4-Dinitrophenol	51-28-5	120	nc	1000	5,nc	Pending		NA		0.014	1
	di-n-Octyl phthalate	117-84-0	1000	5,nc	1000	5,nc	Pending		NA		0.28	2
	1,4-Dioxane	123-91-1	12	c	30	c	Pending		NA		0.0061	1
	Diphenylamine	122-39-4	1000	5,nc	1000	5,nc	Pending		NA		0.17	2
	Ethylene glycol	107-21-1	1000	5,nc	1000	5,nc	Pending		NA		14	2
	Fluoranthene	206-44-0	1000	5,nc	1000	5,nc	1000	5	NA		0.28	1
	Hexachlorobenzene	118-74-1	0.3	c	1.1	c	Pending		NA		0.000022	1
	Hexachlorobutadiene	87-68-3	Pending		Pending		Pending		NA		0.00045	1
	Hexachlorocyclopentadiene	77-47-4	360	nc	1000	5,nc	Pending		NA		0.042	1
	Hexachloroethane	67-72-1	11	c	28	c	Pending		NA		0.0007	1
	Indeno[1,2,3-cd]pyrene	193-39-5	0.22	7,c	3.9	7,c	1000	5	NA		0.0000048	1
	2-Methylphenol	95-48-7	1000	5,nc	1000	5,nc	Pending		NA		0.35	2
	3-Methylphenol	108-39-4	1000	5,nc	1000	5,nc	Pending		NA		0.35	2
	4-Methylphenol	106-44-5	310	nc	1000	5,nc	0.27		NA		0.035	2
	4-Nitrophenol	100-02-7	Pending		Pending		2.1		NA		0.056	1
	N-nitrosodimethylamine	62-75-9	0.003	7,c	0.056	7,c	Pending		NA		0.00000069	1
	N-Nitrosodinpropylamine	621-64-7	0.069	c	0.25	c	0.00000028		NA		0.000005	1
	N-Nitrosodiphenylamine	86-30-6	100	c	350	c	0.67		NA		0.0071	1
	Pentachlorophenol	87-86-5	3	c	9	c	0.07		NA		0.00029	1
	Phenol	108-95-2	1000	5,nc	1000	5,nc	Pending		NA		2.1	1
	Pyrene	129-00-0	1000	5,nc	1000	5,nc	1000	5	NA		0.21	1
	Pyridine	110-86-1	61	nc	620	nc	0.38		NA		0.007	2
	2,4,5-Trichlorophenol	95-95-4	1000	5,nc	1000	5,nc	88		NA		0.7	1
	2,4,6-Trichlorophenol	88-06-2	6.1	nc	62	nc	Pending		NA		0.0032	1
PCBs	Aroclor 1016	12674-11-2	3.9	nc	21	c	1000	5	NA		0.000017	1
	Aroclor 1254	11097-69-1	0.22	c	0.74	c	1000	5	NA		0.000017	1
	Aroclor 1260	11096-82-5	0.22	c	0.74	c	1000	5	NA		0.000017	1
	PCBs	1336-36-3	0.22	c	0.74	c	1000	5	NA		0.000017	1
Pesticides	Aldicarb sulfone	1646-88-4	78	nc	1000	5,nc	Pending		NA		0.007	1
	Aldrin	309-00-2	0.038	c	0.17	c	1000	5	NA		0.0000021	1
	alpha-BHC	319-84-6	0.1	c	0.45	c	0.0017		NA		0.0000056	1
	beta-BHC	319-85-7	0.35	c	1.6	c	Pending		NA		0.00019	2
	gamma-BHC	58-89-9	0.44	c	1.7	c	0.017		NA		0.0002	1
	2,4-D	94-75-7	690	nc	1000	5,nc	2.5		NA		0.07	1
	Dalapon	75-99-0	1000	5,nc	1000	5,nc	1.1		NA		0.2	1
	2,4-DB	94-82-6	630	nc	1000	5,nc	Pending		NA		0.056	2
	4,4'-DDD	72-54-8	2.7	c	12	c	1000	5	NA		0.00015	1
	4,4'-DDE	72-55-9	1.9	c	8.4	c	1000	5	NA		0.0001	1
	4,4'-DDT	50-29-3	1.7	c	7	c	1000	5	NA		0.0001	1
	Dieldrin	60-57-1	0.04	c	0.18	c	1000	5	NA		0.000002	1
	Dinoseb	88-85-7	78	nc	1000	5,nc	0.62		NA		0.007	1
	Endosulfan I	115-29-7	470	nc	1000	5,nc	1000	5	NA		0.042	1
	Endosulfan II	33213-65-9	Pending		Pending		1000	5	NA		0.042	1
	Endosulfan Sulfate	1031-07-8	Pending		Pending		1000	5	NA		0.042	1
	Endrin	72-20-8	23	nc	310	nc	1000	5	NA		0.002	1
	Endrin aldehyde	7421-93-4	Pending		Pending		Pending		NA		0.0021	1
	Heptachlor	76-44-8	0.14	c	0.64	c	1000	5	NA		0.000008	1
	Heptachlor epoxide	1024-57-3	0.07	c	0.31	c	1000	5	NA		0.000004	1
	Isophorone	78-59-1	670	c	1000	5,c	Pending		NA		0.14	1
	MCPA	94-74-6	39	nc	510	nc	Pending		NA		0.0035	2
	MCPP	93-65-2	78	nc	1000	5,nc	Pending		NA		0.007	2
	Methoxychlor	72-43-5	390	nc	1000	5,nc	Pending		NA		0.035	1
	Phorate	298-02-2	16	nc	200	nc	Pending		NA		0.0014	2
	2,4,5-T	93-76-5	780	nc	1000	5,nc	Pending		NA		0.07	2
	Terbufos	13071-79-9	2	nc	26	nc	Pending		NA		0.00018	2
	Toxaphene	8001-35-2	0.58	c	2.6	c	1000	5	NA		0.000032	1
	2,4,5-TP	93-72-1	630	nc	1000	5,nc	Pending		NA		0.05	1

Class	Analyte (CDPHE Preferred Name)	CAS No.	Residential		Worker [4]		Groundwater Protection Level		Leachate Reference Concentration		Water Standard	
			[mg/kg]	Notes	[mg/kg]	Notes	[mg/kg]	Notes	[mg/L]	Notes	[mg/L]	Notes
Explosives	2,4-Dinitrotoluene	121-14-2	120	nc	1000	5,nc	Pending		NA		0.00011	1
	2,6-Dinitrotoluene	606-20-2	61	nc	620	nc	Pending		NA		0.007	2
	2,4/2,6-Dinitrotoluene mix	25321-14-6	0.94	c	4.2	c	Pending		NA		0.00051	2
	HMX	2691-41-0	1000	5,nc	1000	5,nc	Pending		NA		0.35	2
	4-Nitrotoluene	99-99-0	38	c	170	c	Pending		NA		0.021	2
	RDX	121-82-4	5.5	c	24	c	Pending		NA		0.0021	2
	2,4,6-Trinitrotoluene	118-96-7	19	c	79	c	Pending		NA		0.00035	2
Anions	Cyanide (free)	57-12-5	1600	nc	20000	nc	NA		4.4		0.2	1
	Cyanide (hydrogen)	74-90-8	1600	nc	20000	nc	NA		3.1		0.14	2
	Nitrate	14797-55-8	130000	nc	1600000	nc	NA		220		10	1
	Nitrite	14797-65-0	7800	nc	100000	nc	NA		22		1	1

NOTES:

c – Standard based on carcinogenic risk corresponding to a lifetime risk of 1 E-6.

nc – Standard based on non-carcinogenic risk corresponding to a hazard quotient (HQ) of 1. For facilities where multiple non-carcinogenic chemicals are present, HQ values should be divided by a factor of 10 to account for additivity. If adjusted table values are exceeded, consultation with a toxicologist is recommended to assess likely impact on specific target organs.

Pending – Table values shown as pending are under review. Users should contact the Division if they have an urgent need for a table value for a constituent currently shown as pending.

NA – Not applicable; use of this table to select soil evaluation values under Tier 2 does not allow for the calculation of a soil concentration under this column.

1. Water standard based on current state or federal MCL.
2. Water standard based on MCL-equivalent calculation.
3. Water standard based on state agricultural standard.
4. Worker values are considered protective for indoor office workers with occasional contact with outdoor soil, and for outdoor workers engaged in light to moderate activity. **Values are NOT APPLICABLE to outdoor workers routinely engaged in contact-intensive activity.** For facilities where contact intensive use is anticipated, additional analysis and consultation with a toxicologist will be required to determine appropriate site-specific inputs to the risk equations.
5. Table value is capped at an upper concentration limit of 1,000 mg/kg. The Division believes it is necessary to cap the chronic risk scenario and soil-to-groundwater modeling concentration outputs, because the two modeling approaches can result in the calculation of soil concentrations that are very high in an absolute sense, possibly leading to acute health impacts, the presence of free-phase contaminant in soil, or leaving behind constituent levels in soil that might constitute a hazardous waste. Users may contact the Division if they have a need for specific risk-based values, or modeled groundwater concentrations.
6. Based on total chromium.
7. Value based on current EPA-recommended methodology for assessment of chemicals causing cancer through a specific mutagenic mode of action (MOA).
8. Value based on current CDPHE policy for this chemical. Contact the Division if additional information is needed.
9. Table value assumes 3% dermal absorption. Vapor pressure for this volatile organic chemical (VOC) is less than that for benzene, indicating additional potential for dermal absorption. Table values for VOCs with a vapor pressure greater than that of benzene are calculated based on dermal absoption of 0%.
10. For many locations in Colorado, naturally occurring concentrations of arsenic in soil are expected to be higher than the risk-based value listed in Table 1. If adequate background sampling is available that confirms the naturally occurring background concentration of arsenic adjacent to a facility is higher than the table value, the background concentration may be used for site screening and remediation purposes.
11. Screening levels for lead are based on chemical-specific models, rather than the EPA Region 9 risk algorithm used to derive other table values. The residential value is based on default inputs to EPA's IEUBK model for lead in children. The worker value is based on EPA's adult lead model (ALM), using default values recommended in EPA's 2002 review of CDC's NHANES III report. Consideration of site-specific inputs to the IEUBK or ALM lead models and consultation with a toxicologist is strongly recommended for facilities with lead levels in soil that exceed the residential or worker table values. Contact the Division for additional information about details of the lead models and site-specific considerations.

APPENDIX E

Physical Characteristic Data

Physical Characteristics of CDOT Sampled Traction Sand (Percent Passing of Sieve Sizes)

Sample Location	3/4 inch	1/2 inch	3/8 inch	No. 4	No.10	No. 16	No. 40	No. 50	No. 100	No. 200
Vail Pass Roadside Mix (2272)	100	100	98	91	74	56	37	21	10	5
Berthoud Pass (2273)	100	100	100	94	69	43	25	13	6	2.7
Vail Pass Roadside(2275)	100	99	98	86	44	27	15	8	4	3.8
Vail Pass WQ Basin (2276)	100	100	100	96	69	51	36	26	19	17
I-70, Frisco to Copper Mountain	100	N/A	94.6	84.1	62.4	N/A	28.1	N/A	12.9	8.9
I-70, East Eisenhower	100	N/A	98.8	87.5	58.3	N/A	25.4	N/A	12.4	9.2
US 40, Empire-Berthoud Falls	100	N/A	97.3	85.8	41.2	N/A	10.9	N/A	5.4	4.1
US 40, Berthoud Pass East	100	N/A	98.6	86.4	45.4	N/A	16.8	N/A	8.5	6.2
US 40, Berthoud Pass West	100	N/A	99.4	79.7	32.3	N/A	8.8	N/A	4.5	3.1
SH9, Hoosier Pass North	100	N/A	99.5	83.7	54.9	N/A	21.2	N/A	11.1	7.8
I-70, Copper Mt. to Vail Pass	100	N/A	98.4	89.1	70.6	N/A	33.1	N/A	15.9	10.9
I-70, Vail Pass to E. Vail	100	N/A	99.5	88.5	66.2	N/A	29	N/A	13.1	8.4
Vail Sand Berm, S. side	100	N/A	100	93.2	72.4	N/A	33.5	N/A	15.4	10.2
I-70, Eisenhower T. East	100	N/A	83.9	76.8	66.2	N/A	47.3	N/A	33.7	27.3
I-70, Eisenhower T. West	100	N/A	99.1	89.8	70.9	N/A	32.4	N/A	15.1	10
US 40, Berthoud Pass East	100	N/A	99.6	89.2	65.1	N/A	25.6	N/A	10.4	6.7
US 40, Berthoud Pass West	100	N/A	99.3	88.4	59.5	N/A	25.8	N/A	13.1	9.2
I-70, Vail Pass to E.Vail	100	N/A	100	92.3	72.2	N/A	30.4	N/A	13.5	9.2
I-70, Vail Pass to Officers Gulch	100	N/A	100	94.5	74.1	N/A	34.2	N/A	15	9.5
I-70, Eisenhower Tunnel West	100	N/A	95.3	89.7	74.4	N/A	33.9	N/A	14.9	10
I-70, Silver Plume to Empire	100	N/A	96.6	89.4	65.2	N/A	29.1	N/A	13.9	9.8
US 40, Empire to Berthoud Falls	100	N/A	96.9	83.6	57.7	N/A	21.9	N/A	9.1	6.1
SH9, Alma to Hoosier Pass	100	N/A	93.2	73.7	48.9	N/A	17.6	N/A	9.3	7.2
Composite of CDOT Samples	100	N/A	99	92	76	N/A	35	N/A	0	9
R1 Environmental - Road	100	98.4	97.9	89.5	73.3	61.5	36.3	27.9	16.4	10.4
R1 Environmental - Basin	99.5	97.4	95.7	87.5	65.1	49.6	23.9	17.2	9	4.9
Standard Deviation	0.10	1.08	3.35	5.25	11.77	12.03	8.89	7.65	6.29	4.87
Mean	99.98	99.13	97.64	87.75	62.63	48.02	27.43	18.85	11.98	8.72
Mean plus 1 SD	100.08	100.21	100.99	92.99	74.39	60.05	36.32	26.50	18.28	13.58
Mean minus 1 SD	99.88	98.06	94.29	82.50	50.86	35.98	18.54	11.20	5.69	3.85

Comparison to CDOT Aggregate Specifications

Table 703-3	3/4 inch	No. 4	No. 200
Class 1	--	(30-65) Failed	(3-15) Pass
Class 2	--	--	(3-15) Pass
Class 3	--	--	(20 max) Pass
Class 4	(50-90) Failed	(30-50) Failed	(3-12) Pass/Fail
Class 5	--	(30-70) Failed	(3-15) Pass
Class 6	(100) Pass	(30-65) Failed	(3-12) Pass/Fail
Class 7	--	--	(5-15) Pass/Fail

Table 703-4	3/4 inch	1/2 inch	No. 8	No. 200
Grading SX	(100) Pass	(90-100) Pass	na	(2-10) Pass/Fail
Grading S	(90-100) Pass	Pass	na	(2-8) Pass/Fail
Grading SG	--	Pass	na	(1-7) Pass/Fail

Table 703-5	3/4 inch	1/2 inch	No. 4	No. 8	No. 30	No. 200
9.5 mm nominal	--	(100) Pass	(30-55) Fail	na	na	(8-12) Pass/Fail
12.5 mm nominal	--	(100) Pass	(24-32) Fail	na	na	(8-12) Pass/Fail
19.0 mm nominal	(100) Pass	(85-95) Fail	(24-32) Fail	na	na	(8-12) Pass/Fail

Table 703-6	3/4 inch	1/2 inch	3/8 inch	No. 4	No. 200
9.5 mm Type I	--	--	(100) Pass/Fail	(0-15) Fail	(0-1.0) Fail
12.5 mm Type II	--	(100) Pass	(70-100) Pass/Fail	(0-4) Fail	(0-1.0) Fail
19.0 mm Type IV	(100) Pass	(95-100) Pass	(60-80) Fail	--	(0-1.0) Fail

Table 703.06	No. 30	No. 50	No. 200
Mineral Filler	na	(95-100) Fail	(70-100) Fail

Table 703-7	3/4 inch	No .4	No. 16	No. 50	No. 100	No. 200
Class A Filter Material	(20-90) Fail	(0-20) Fail	--	--	--	(0-3) Fail
Class B Filter Material	--	(20-60) Fail	(10-30) Fail	(0-10) Fail	--	(0-3) Fail
Class C Filter Material	(100) Pass	(60-100) Pass	--	(10-30) Pass	(0-10) Pass/Fai	(0-3) Fail

Table 703.07	3/4 inch	No. 4	No. 200
Bed Material	(100 3-Inch) Pass	(20-65) Fail	(0-10) Pass/Fail

Table 703.08	3/4 inch	No. 4	No. 50	No. 200
Class I Material	(100 2-Inch) Pass	(30-100) Pass	(10-60) Pass	(5-20) Pass

Table 703.10	3/4 inch	3/4 inch	3/4 inch
Aggregate	(100 2.5-Inch) Pass	(95-100 2-Inch) Pass	(0-15) Fail

🟩	= Mean, Mean + 1 SD, and Mean - 1 SD all meet associated requirement
🟨	= Some of the Mean, Mean + 1 SD, or Mean - 1 SD meet associated requirement
🟥	= None of the Mean, Mean + 1 SD, and Mean - 1 SD meet associated requirement

APPENDIX F
Composting Test Photographs

Tub 1, December, 2008

Tub 2, December, 2008

Tub 3, December, 2008

Tub 4, December, 2008

Tub 1, December, 2008

Tub 2, December, 2008

Tub 3, December, 2008

Tub 4, December, 2008

Tub 1, July, 2009

Tub 2, July 2009

Tub 3, July 2009

Tub 4, July 2009

Tubs 1 and 2 - Sept, 2009

Tubs 3 and 4 – Sept, 2009

Site View looking NW

Site View looking SE

APPENDIX G

BioComp® Analytical Results

A1 ORGANICS, 16350 WCR 76, Eaton, CO 80615 Ph 970-454-3492 Fax 970-454-3232

BioComp® Analyticals

Class I Product

A course particle compost produced from non-hazardous, non-toxic organic biosolids and various bulking agents, like brewers grain, cellulose fiber, and clean untreated/unpainted wood.

Date of latest test: **18-Nov-08**

Unless otherwise indicated, the following data is an average of the four most recent tests.

Compost Parameters	**Reported as:** (Units of measure)	**Test Results**	**Test Results**
Plant Nutrients	***% Weight basis***	***% Wet weight basis***	***% Dry weight basis***
NITROGEN	Total N	0.70	1.12
Ammonia	NH_4-N	0.00	0.00
Nitrate	NO_3-N	0.10	0.13
Organic Nitrogen	Org. N	0.62	0.99
PHOSPHORUS	P_2O_5	0.86	1.33
Phosphorus	P	0.38	0.60
POTASSIUM	K_2O	0.24	0.39
Potassium	K	0.20	0.32
CALCIUM	Ca	0.82	1.30
MAGNESIUM	Mg	0.20	0.31
SULFATE	SO_4	0.08	0.12
Moisture Content	*% Wet weight basis*	37%	
Organic Matter Content	*% Dry weight basis*		32.93%
pH	*Units*	5.90	
Soluble Salts (electrical conductivity EC)	*dS/m (mmhos/cm)*	2.83	
Particle Size	*% Under 9.5 mm, dw basis*	99.6%	
Carbon to Nitrogen	C:N Ratio	12	
Ammonia NH_4-N to Nitrate $N0_3$-N Ratio	A:N Ratio	0.03	

Maturity Indicator (bioassay)		Average Maturity Indicator:	Maturity Indicator from the most recent test:
Percent Emergence	Average % of control	100%	100.0%
Relative Seedling Vigor	Average % of control	100%	100.0%

Stability Indicator (Stability is a measure of the respiration rate, biologically available carbon, porosity, nutrients, pH and microbes. A rating of "stable or very stable" provides for optimal growing conditions.)

Most Recient Stability Rating:

Very Stable

Select Pathogens	**PASS/FAIL** Per US EPA Class A standard, 40 CFR 503.32(a)	Pass	
Trace Metals	**PASS/FAIL** Per US EPA Class A standard, 40 CFR 503.13	Pass	

Average Bulk Density
(lbs/CY)

1,053

“This compost product has been sampled and tested as required by the Seal of Testing Assurance Program of the United States Composting Council (USCC). Test results are available upon request by calling A1 Organics at (970)454-3492.