ROCKY MOUNTAIN ARSENAL

ANNUAL COVERS REPORT FOR INTEGRATED COVER SYSTEM 2018

Revision 0

November 15, 2018

U.S. Department of the Army

Shell Oil Company

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00058904 23463 - 3

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ACRONYMS

°F	degrees Fahrenheit
ACR	Annual Covers Report
AMA	Army Maintained Areas
BBM	Biota Barrier Material
CAT	Complex (Army) Trenches
CMPA	Corrective Measures Plan of Action
CPSM	Cover Perimeter Survey Monuments
FY17	Fiscal Year 2017
FY18	Fiscal Year 2018
FY19	Fiscal Year 2019
GPS	Global Positioning System
ICS	Integrated Cover System
LTCP	Long-Term Care Plan
NRAP	Non-Routine Action Plan
O&M	Operations and Maintenance
OCN	O&M Change Notice
OMC	Operations and Maintenance Contractor
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RMITS	Records Management Information Technology System
SCMMS	Soil Cover Moisture Monitoring System
SDT	Shell Disposal Trenches
SOP	Standard Operating Procedure

EXECUTIVE SUMMARY

This 2018 Annual Covers Report (ACR) for the Integrated Cover System (ICS) at the Rocky Mountain Arsenal Federal Facility Site was prepared in accordance with the *RCRA-Equivalent, 2-, and 3-Foot Covers Long-Term Care Plan,* Revision 2 (LTCP) (TtEC 2011). The purpose of this ICS ACR is to document cover inspection results and maintenance activities performed on the ICS during the reporting period, and to describe future plans to improve or sustain cover condition. This ICS ACR documents maintenance-related activity performed on the ICS Army Maintained Area (AMA) during the Fiscal Year 2018 (FY18), that is, between October 1, 2017 and September 30, 2018.

The ICS is currently in the Interim Operations and Maintenance (O&M) Period defined in Section 1.0 of the LTCP. This report addresses the ninth year of Interim O&M for the ICS since construction was completed in early 2010.

The Soil Cover Moisture Monitoring System (SCMMS) was operated and maintained in accordance with the *SCMMS O&M Plan* (TtEC 2006) and associated Standard Operating Procedures (SOPs). The SCMMS database, which manages data produced by various types of instrumentation installed in the Shell Disposal Trenches (SDT) Resource Conservation and Recovery Act (RCRA)-Equivalent Cover, was maintained by the Army's Records Management Information Technology Services Contractor. The database contains precipitation data collected from a rain gauge located near Lysimeter 002, percolation data collected from tipping buckets located in each of the SDT cover lysimeter manholes, and soil moisture and temperature data. On October 25, 2017, O&M Change Notice (OCN)-LTCP-2017-001 was approved by the Regulatory Agencies, changing the reporting requirements for the SCMMS. Rather than being reported quarterly, data collected by the SCMMS will be provided to the Regulatory Agencies on an annual basis as part of the ACR for ICS.

The combined total precipitation measured at Rocky Mountain Arsenal by the rain gauge located near Lysimeter 002 between October 1, 2017 and September 30, 2018 was 8.35 inches.

In general, the cover on ICS was in good condition throughout FY18. Cover deficiencies observed during the reporting period included differential settlement, burrowing animal holes, noxious or undesirable weeds, and repairs to the cover soil around erosion monuments. All cover soil thickness loss measurements were below the non-routine action trigger level and the compliance standard.

Beginning FY18, the quarterly submission of percolation monitoring results for all cover lysimeters were issued to the Regulatory Agencies and included three tables spanning six months of data. The three tables include monthly measurements, 9-month cumulative totals, and 12-month cumulative totals. All of the ICS lysimeters during FY18, except Lysimeter 014, were well below the non-routine action trigger level and the compliance standard for the entire year.

In previous reporting years, the SDT lysimeters and Lysimeter 004 were out of compliance and investigations were conducted to find the root cause. Beginning in June of 2018, a Cover Soil Field Investigation – Phase 2 was conducted for the SDT lysimeters and Lysimeter 004. The objective of the Cover Soil Field Investigation – Phase 2 was intended to do three things:

provide visual indications of preferential flow paths through the cover soil, address shortcomings in the Phase 1 Field Investigation geotechnical data, and investigate the potential for standing water in the void space of the 50-foot Biota Barrier Material (BBM) runout. The Data Summary Report for the field investigation is scheduled for issuance in December 2018.

The 2018 Vegetation Performance Assessment was conducted in accordance with SOP 002 of the LTCP, Revision 2. Separate assessments were performed on the ICS RCRA-equivalent covers and on the ICS 2-foot and 3-foot soil covers. In all, data from 45 vegetation transects were collected. The dates on which the assessments were conducted were generally inside the range specified in LTCP SOP 002. Total live vegetation values were well above the compliance standard of 25 percent for all areas. The two-year average of total ground cover was also comfortably above the compliance standard of 50 percent for all cover areas, and the three-year running average of total ground cover was also well above the compliance standard of 67 percent.

Cost incurred performing Interim O&M of the ICS AMA during FY18, including inspections, repairs, and maintenance, was $117,251. A complete budget for Fiscal Year 2019 (FY19) has not been approved as of the issuance of this report. However, the FY19 budget is estimated to be approximately $150,301.

In summary and based on the information presented in this report, corrective actions are required to address exceedance of the percolation compliance standard at Lysimeters 001, 002, 003, 004, and 014. The Army intends to perform corrective actions to address percolation performance once the cause(s) of the excessive percolation have been determined and the Regulatory Agencies approve the Corrective Measures Plan(s) of Action (CMPA).

Recommendations for FY19 include:

- The Army and Shell recommend using the available information and the consultative process with the Regulatory Agencies to develop a CMPA for the SDT RCRA-Equivalent Cover. This CMPA should attempt to restore the soil cover conditions over the lysimeter pans and represent the larger SDT RCRA-Equivalent Cover, to the maximum extent possible.
- Install piezometers in the low-lying areas of the BBM runout of the SDT RCRA-Equivalent Cover and perform water level monitoring.
- Finalize a *Schedule for Investigation of Percolation Exceedance of Lysimeter 014 and Development of a Corrective Measures Plan of Action.*
- The site should be examined for weeds throughout FY19. Occurrences of cheatgrass, Canada thistle and other noxious weeds should be spot sprayed.
- The site should continue to be examined for erosion rills or gullies, ponding areas, excessive tire tracks and ruts, burrowing animal holes, and localized settlement.

These recommendations are planned for FY19 and will be discussed in the 2019 ICS ACR.

1.0 INTRODUCTION

This 2018 Annual Covers Report (ACR) for the Integrated Cover System (ICS) at the Rocky Mountain Arsenal Federal Facility Site was prepared in accordance with the *RCRA-Equivalent, 2-, and 3-Foot Covers Long-Term Care Plan,* Revision 2 (LTCP) (TtEC 2011). The purpose of this ICS ACR is to document cover inspection results and maintenance activities performed on the ICS during the reporting period, and to describe future plans to improve or sustain cover conditions. This ICS ACR documents maintenance-related activity performed on the ICS Army Maintained Area (AMA) during Fiscal Year 2018 (FY18), that is, between October 1, 2017 and September 30, 2018.

The ICS is currently in the Interim Operations and Maintenance (O&M) Period defined in Section 1.0 of the LTCP. This report addresses the ninth year of Interim O&M for the ICS since construction was completed in early 2010.

2.0 METHODOLOGY

The Resource Conservation and Recovery Act (RCRA)-equivalent, 2-foot, and 3-foot covers and associated non-cover areas within the outside shoulder of the perimeter access road, collectively referred to as the ICS AMA, were inspected, monitored, repaired, and maintained in accordance with the LTCP, Revision 2 and related Standard Operating Procedures (SOPs), and the *Soil Cover Moisture Monitoring System* (SCMMS) *O&M Plan* (TtEC 2006). The results of inspections and monitoring of vegetation, percolation, and cover soil thickness were used to verify cover performance and to trigger cover maintenance and repair work.

2.1 Type I and Type II Cover Inspections

The procedure for inspecting soil cover conditions and infrastructure features is detailed in LTCP SOP 001, *Cover Conditions Inspections*. This SOP includes procedures for Type I and Type II cover inspections, as well as a procedure for collecting cover soil thickness data, which were used to evaluate the actual cover soil thickness against the cover soil thickness compliance standard. Where feasible, multiple inspections were conducted concurrently for efficiency and to minimize traffic on the cover. For example, Type I inspections were implemented concurrently with the Type II inspections. Copies of the cover inspection forms are provided in Appendix D.

2.2 Vegetation Performance Assessment

LTCP SOP 002, *Cover Vegetation Performance Assessment*, provides the procedure to collect and document vegetation conditions for assessment and future management. This SOP includes a procedure for conducting the annual quantitative vegetation survey. Data collected in accordance with LTCP SOP 002 were used to evaluate the vegetation against the vegetation performance standard. The results of the evaluation are presented in Section 6.1.1. Refer to Appendix C for photos and other information collected during the 2018 Vegetation Performance Assessment.

2.3 Percolation Monitoring

The procedure for collecting percolation data and operating the lysimeters is provided in LTCP SOP 003, *Percolation Monitoring System Data Collection and Operation*. Data collected in accordance with LTCP SOP 003 were used to evaluate the measured percolation against the

percolation compliance standard. Monthly percolation measurements from all ICS lysimeters are provided in Table 7.1-1.

The percolation data for the Shell Disposal Trenches (SDT) RCRA-Equivalent Cover lysimeters is recorded by automated tipping buckets. Percolation data collected by the automated tipping buckets in the SDT RCRA-Equivalent Cover lysimeters are provided in Appendix B.

2.4 Soil Cover Moisture Monitoring System

The SCMMS was operated and maintained in accordance with the *SCMMS O&M Plan* and associated SOPs. The SCMMS database, which manages data produced by various types of instrumentation installed in the SDT RCRA-Equivalent Cover, was maintained by the Army's Records Management Information Technology Services (RMITS) Contractor. The database contains precipitation data collected from a rain gauge located near Lysimeter 002, percolation data collected from tipping buckets located in each of the SDT cover lysimeter manholes, and soil moisture and temperature data. Information regarding the SCMMS is presented in Section 9.0, and moisture sensor data are located in Appendix B. The precipitation and percolation data are described in Sections 3.0 and 7.0, respectively.

2.5 Maintenance and Repair Activities

Routine maintenance and repair activities are listed in Table 3.2-1 of the LTCP, while conditions requiring non-routine actions are listed in Table 3.2-2 of the LTCP. There were no non-routine actions performed on the ICS AMA in FY18. Routine maintenance and repair activities performed in FY18 are discussed in Section 4.0 of this report.

3.0 PRECIPITATION AND WEATHER CONDITIONS

Precipitation is recorded at the SDT RCRA-Equivalent Cover by a rain gauge located near Lysimeter 002. The combined total precipitation measured between October 1, 2017 and September 30, 2018 was 8.35 inches. Precipitation data are provided in Appendix A.

3.1 National Weather Service Summary

The following evaluations of weather conditions for the Rocky Mountain Region between October of 2017 and September of 2018 are based on information published by the National Oceanic and Atmospheric Administration, National Weather Service (NWS) Forecast Office for Denver/Boulder, Colorado. Climate data reported by the NWS were collected at the Primary Local Climatological Data Site, located at the Denver International Airport. All temperatures are reported in degrees Fahrenheit (°F).

The fall months of 2017 were variable in temperature and precipitation. The total precipitation for the month of October 2017 was 1.33 inches, which was 0.31 inches above the historical norm of 1.02 inches. November recorded 0.25 inches of precipitation, which was 0.36 inches below normal and December of 2017 recorded 0.15 inches of precipitation, which was 0.2 inches below normal. October finished the month by being 0.8 °F below normal. November wrapped up 7 °F above normal, which ranked November of 2017 as the tenth warmest November on record since temperature records began in 1872. December also finished slightly warmer at 3.2 °F above normal.

The 2018 winter months for the Rocky Mountain Region were fluctuating in temperature and precipitation. January 2018 recorded above normal temperatures and precipitation, February was cold and unsettled, and March experienced above normal temperatures and precipitation. The average temperature for January was 34.7 °F, which was 4.0 °F above normal. February's average temperature was 29.9 °F, which was 2.6 °F below normal and March's average temperature was 42.7 °F, which was 2.3 °F above normal. The total precipitation for the month of January 2018 was 0.54 inches, which was 0.13 inches above the historical norm of 0.41 inches. February of 2018 recorded 0.31 inches of precipitation, which was 0.06 inches below normal and March of 2018 recorded 1.02 inches of precipitation, which was 0.10 inches above normal. January recorded 6.4 inches of snow during the month, which was 0.6 inches below normal. February recorded 6.2 inches of snow, which was 0.5 inches above normal. March recorded 4.8 inches of snow, which was 5.9 inches below the normal of 10.7 inches.

The 2018 spring months for the Rocky Mountain Region started off drier and with near normal temperatures in April, May proved to have near average precipitation and was the eighth warmest May on record, and June wrapped up with below average precipitation and was the seventh warmest June on record. The average temperature for April 2018 was 47.8 °F, which was 0.4 °F above normal. The average temperature for May 2018 was 61.4 °F, which was 4.3 °F above normal. Two record high temperatures were set or tied in May 2018. A record high of 90 °F was reached on the 10th and a tie of 91 °F on the 25th. In addition, there were four days during the month in which the high temperature reached or exceeded the 90 °F mark. This breaks the record of 90 degrees days for the month of May. The average June temperature was 72.4 °F, which was 5.0 °F above normal. Three record high temperatures were set or tied in June 2018. A record high of 95 °F was tied on the 5th, another tie of 95 °F on the 6th, and a record smashing 105 °F reached on the 28th. The record high temperature of 105 °F also ties Denver's all-time record high temperature. The total precipitation for the month of April 2018 was 0.86 inches, which was 0.85 inches below the historical norm of 1.71 inches. May of 2018 recorded 1.86 inches of precipitation, which was 0.26 inches below normal. June of 2018 recorded 0.43 inches of precipitation, which was 1.55 inches below normal.

The 2018 summer months for the Rocky Mountain Region started off drier and warmer than average in July, August experienced near normal temperatures and below average precipitation, and September wrapped up to be warmer with below average precipitation. The average temperature for July was 75.3 °F, which was 1.1 °F above normal. August's average temperature was 72.4 °F, which was 0.1 °F below normal. September's average temperature was 67.8 °F, which was 4.4 °F above normal. This ranks September 2018 the sixth warmest since records began in 1872. The total precipitation for the month of July 2018 was 1.03 inches, which was 1.13 inches below the historical norm of 2.16 inches. August of 2018 recorded 0.93 inches of precipitation, which was 0.76 inches below normal and September of 2018 recorded 0.18 inches of precipitation, which was 0.78 inches below normal.

3.2 Significant Storm Events at RMA

Precipitation is monitored locally at RMA using two rain gauges, both of which are located in Section 36. These rain gauges are positioned near Lysimeter 002 on the SDT RCRA-Equivalent Cover, and near the Lime Basins Metering Building, located west of the Lime Basins RCRA-Equivalent Cover. The Lime Basins rain gauge is typically used to record precipitation values for RMA.

RMA experienced two significant storm events between October of 2017 and September of 2018. These events occurred on July 23 and July 25, 2018. A significant storm event is defined as a rain storm event in which greater than 1.0 inch of precipitation falls within 24 hours. On July 23 the Lime Basins rain gauge recorded 1.24 inches of precipitation. The storm that occurred on July 25 also produced 1.24 inches of precipitation, but was much more severe and included a large amount of hail that was not represented in the precipitation total. Some of the hail was quite large and caused damage to vehicles and structures on site. Neither of these significant storms is represented in the NWS climatological data provided in Section 3.1, illustrating the scattered nature that severe storms often exhibit on the front range of the Rocky Mountain Region.

4.0 SOIL COVER ASSESSMENT, MAINTENANCE AND REPAIR ACTIONS

During FY18, the condition of the ICS AMA was inspected during the Type I, Type II, and Post-Storm inspections in accordance with the LTCP. Type I inspections were conducted on December 13, 2017, and on March 7, May 2, June 6, and July 3, 2018. The spring Type II inspection was conducted on April 10, 2018 and the fall Type II inspection was conducted on September 19, 2018.

There were two significant storm events that occurred in FY18 where the RMA received more than one inch of precipitation in a 24-hour period. The significant storm events recorded by the Lime Basins rain gauge occurred on July 23 and July 25, 2018. The Operations and Maintenance Contractor (OMC) staff drove the perimeter road and access roads following each significant storm and documented all observations in the project logbook. Post-Storm inspections were performed when field conditions improved, minimizing the potential for damaging the cover. The Post-Storm inspection was performed on August 1, 2018.

The soil covers were inspected for the following:

- Surface Conditions
- Vegetative Cover
- Engineering and Access Controls
- Monthly Percolation Monitoring - Lysimeters
- Surface Drainage Controls
- Erosion/Settlement Monuments
- Other deleterious conditions

In general, the cover on ICS was in good condition throughout FY18. Observations made during the reporting period are described below and cover inspection documentation is located in Appendix D. The repair actions associated with these observations are shown on Figure 4.0-1 and are also described below.

4.1 Differential Settlement

In April of 2016, OMC personnel and two representatives from Pacific Western Technology (contractor for the U.S. Environmental Protection Agency) met at the location of differential settlement that had been observed on the Complex (Army) Trenches (CAT) RCRA-Equivalent

Cover and documented in the 2014 ICS ACR (Navarro 2014). The purpose of the field visit was to establish a monitoring area of the differential settlement (or holes on the soil surface); however, upon inspection it was difficult to find a concentrated number of holes to establish a monitoring area. Most of the holes identified in 2014 had self-healed and the inspectors were not able to relocate them. OMC personnel returned to the area in May of 2016 to identify individual holes for long-term monitoring. A total of 22 holes were identified for monitoring purposes. Each hole was surveyed, photographed, and measured (width north/south, width east/west, and depth). The monitoring of the 22 identified holes continued into Fiscal Year 2017 (FY17) and FY18. The holes were measured in November of 2016 and May of 2017 and were found to have consistently decreased in size and observed to have increased vegetation around or in the holes. The holes were monitored again in November of 2017 and it was determined that the holes were all decreasing in size and increasing in vegetation and thus the monitoring of the hole activity was discontinued.

During the fall 2017 Type II inspection, an area of differential settlement was identified at waypoint 011 on the north transects. This area was repaired using cover soil from the Long Term Cover Soil Stockpile in March of 2018.

Two areas of differential settlement were observed and marked with Global Positioning System (GPS) coordinates during the spring 2018 Type II inspection. These depressions were repaired with cover soil in September of 2018.

An area of differential settlement was identified northwest of Lysimeter 008 during the May 2018 Type I inspection. This depression was repaired with cover soil in September of 2018.

While performing routine maintenance on the ICS cover, areas of differential settlement were observed and marked with GPS coordinates. These areas were not recorded on inspection forms, but were repaired in March and September of 2018. Figure 4.0-1 shows all of the areas that were repaired using cover soil. Cover maintenance documentation is located in Appendix E.

4.2 Burrowing Animal Holes

Many animal holes were identified around the perimeter of the RCRA-equivalent covers during the fall 2017 Type II inspection. These holes were repaired in March of 2018 using cover soil from the Long Term Cover Soil Stockpile.

Animal holes were again observed and marked using handheld GPS devices during the spring 2018 Type II inspection. These holes were repaired in September of 2018 using cover soil.

While performing routine maintenance on the ICS cover, areas of burrowing animal holes were observed and marked with GPS coordinates. These areas were not recorded on inspection forms, but were repaired in March and September of 2018. Figure 4.0-1 shows all of the areas that were repaired using cover soil. Cover maintenance documentation is located in Appendix E.

4.3 Cover Perimeter Survey Monuments

The Cover Perimeter Survey Monuments (CPSMs) were inspected and surveyed in November of 2014 as a part of the Five Year Review. During this inspection, two CPSM tags were noted to

need repair. The tag for CPSM 21 was noted to be bent and the tag for CPSM 62 was missing. These repairs did not happen in FY18 and will therefore be discussed in the 2019 ICS ACR.

4.4 Conditions that Could Interrupt Cover Drainage

During the fall 2018 Type II inspection, a hole was observed on the northwest portion of ICS and marked with Waypoint 012. This area was not repaired during FY18 and will therefore be discussed in the 2019 ICS ACR.

4.5 Noxious or Undesirable Weeds

Canada and Musk thistles were identified on many areas of ICS. Weed control efforts were performed frequently and as needed during FY18. Also, an area of knapweed was identified near the Lime Basins metering building. OMC sprayed this area of knapweed with Milestone®, Rifle-D®, and surfactant in July of 2018.

A combination of herbicides was applied as a ground clear in November of 2017 along the shoulders of the ICS roadways, the cattle guards, the well pads on the Lime Basins access road, around the Lime Basins Metering Building, and gate entrances. The combination included Esplanade®, Perspective®, Arsenal®, Telar® and Roundup®.

There were several areas of cheatgrass that were observed during the fall 2017 Type II inspection. These areas were sprayed using Esplanade® and Roundup® in November of 2017.

There were several areas of cheatgrass that were observed during the fall 2018 Type II inspection. These areas are scheduled to be sprayed during Fiscal Year 2019 (FY19) and will be discussed in the 2019 ICS ACR.

4.6 Lysimeters

OMC pumped the standing water from inside of the lysimeter manholes as needed. When water accumulates inside of the manholes, it complicates the process of measuring percolation. Lysimeters 005, 007, 008, 009, 011, 012, and 013 were pumped in January of 2018. Lysimeters 004, 006, 010, and 014 were pumped in September of 2018.

4.7 Perimeter Fence

In December of 2017, March of 2018, and April of 2018, OMC personnel cleaned tumble weeds off the ICS perimeter fence using a tractor and tumble weed fence equipment.

During the fence cleaning in April of 2018, it was realized that a wooden fence post on the west ICS perimeter fence was broken due to high winds pressing against tumble weeds that had accumulated against the fence. This broken post was removed and replaced in April of 2018.

4.8 Erosion Rills and Holes in the Channel

A hole was identified in the grass lined outlet end of Channel 13 during the December 2017 Type I inspection. This hole was repaired with cover soil in March 2018. During routine maintenance of the cover later in the year, it was noticed that this hole in Channel 13 had reopened. This hole was repaired in September of 2018 using 4-inch minus rock to plug the hole and then backfilled with cover soil.

4.9 Debris Present in the Channel

During the July 2018 Type I inspection, cottonwoods were observed growing in the rip rap outlet of Channel 16. In July of 2018 the cottonwoods were sprayed with herbicide and in September of 2018 the cottonwoods were removed with tree loppers.

4.10 Cracked or Degraded Concrete

During the fall 2018 Type II inspection, an observation was made that there is some caulk missing between some of the concrete joints in Channel 11A. This was not repaired during FY18 and will therefore be discussed in the 2019 ICS ACR.

4.11 Erosion Monuments

During the fall 2017 Type II inspection, it was observed that erosion monument ER21 needed the cap glued back on. This repair was made in September of 2018. During the fall 2017 Type II inspection, it was noted that ER75 sits in a localized depression. This monument had cover soil placed around it in September of 2018 to return the area to grade. During the spring 2018 Type II inspection, it was noted that erosion monuments ER36 and ER86 sit in localized depressions. These areas had cover soil placed around them in September of 2018 to bring them to grade.

During the fall 2018 Type II inspection, it was identified that ER19's Carsonite Marker had been knocked down and ER46 and ER76 could use some additional soil added around the monument. These items were not repaired during FY18 and will be discussed in the 2019 ICS ACR.

5.0 COVER SOIL THICKNESS LOSS

The ICS RCRA-equivalent covers and 3-foot cover includes a network of 92 erosion/settlement monuments embedded within the cover soil. The monuments are generally positioned on a 500-foot grid, except for on the SDT RCRA-Equivalent Cover, where monuments are positioned at locations selected by the Regulatory Agencies during the design process. Cover soil thickness loss was measured at each of the monuments during the Type II inspections in April and September of 2018 in accordance with SOP 001, *Cover Conditions Inspections*. The measurements for each monument are provided on Table 5.0-1. All cover soil thickness loss measurements were below the compliance standard of 0.5 foot.

6.0 VEGETATION PERFORMANCE ASSESSMENT

The 2018 Vegetation Performance Assessment was conducted in accordance with SOP 002 of the LTCP, Revision 2. Results of the assessment are summarized on Table 6.0-1. Appendix C includes additional tables that provide cover and frequency by species, expanded vegetation performance assessments providing two and three year running average comparisons, sample adequacy checks, and raw transect data. Separate assessments were performed on the following areas:

- ICS RCRA-Equivalent Covers (30 transects sampled between September 17 and September 21, 2018);
- ICS 2-Foot and 3-Foot Soil Covers (15 transects sampled on September 5 and 6, 2018).

In all, data from 45 vegetation transects were collected in September of 2018 for the ICS Cover areas. Figures 1 and 2 in Appendix C illustrate transects sampled on the ICS. The dates on

which the assessments were conducted were generally inside the range specified in LTCP SOP 002. Prior to performing the assessments, transect locations and compass bearings were randomly selected using Geographical Information System software. Photos, provided in Appendix C, were taken along the compass bearing at the start of each 50-meter transect. A total of 100 observations were made along each transect. All plant species that were present within one meter on either side of the 50-meter transect, but had not been observed using the point-intercept sampling method, were tallied and used to calculate species density (species per 100 square meters). Appendix C includes cover and frequency summary tables as well as vegetation performance assessment tables for each of the sample areas. These tables meet the reporting requirements set forth by the *Revegetation of the Basin A Soil Cover*, developed during the Basin A dispute resolution process in 1999.

Although the growing season generally had above average temperatures and below normal precipitation, warm season species were prolific at the time the vegetation assessment was conducted. However, cool season plants were somewhat diminished in stature. There did not appear to be excessive stress due to low soil moisture or biological stressors on the grassland community at the time of the assessment. Insects and other wildlife, such as small rodents, grassland birds and deer were observed on all of the areas. A few more plant species not previously noted for the ICS Covers in past years were observed. The increase in species diversity may be an indication of both continued development of plant community complexity, as well as improved performance by individual established plants.

6.1 ICS RCRA-Equivalent Covers

After the 2018 growing season, the areas of the ICS RCRA-equivalent covers continued to be dominated by cool season species. Based on 30 transects sampled, cool season grasses, primarily western wheatgrass *(Pascopyrum smithii)*, provided an average cover of about 40 percent. Cover by seeded warm season species increased from previous years and represented 15 percent cover on average. Weedy species contributed an average cover of less than one percent continuing the trend of very low cover by weedy species on the ICS in general. Average cover by litter was about 41 percent.

6.1.1 Comparison to the Performance Standard

Total live vegetation was estimated to be 56 percent, well above the performance standard of 25 percent. Total ground cover was very high at 97 percent, and corresponding bare ground was 3 percent. The two-year running average for absolute total ground cover was 96 percent, well above the standard. The three-year running average for absolute total ground cover was 94 percent, also well above the standard.

6.1.2 Comparison to the Non-Routine Action Trigger Level

The results of the quantitative vegetation assessment performed on the ICS RCRA-equivalent covers determined that less than one percent of the total live vegetation (relative cover) was comprised of undesirable annual or biennial species. Therefore, the results of comparison to the non-routine action trigger level evaluation are identical to those of the vegetative performance standard described in Section 6.1.1 because cover by undesirable annual and biennial species did not exceed 10 percent of the total live vegetation. The absolute live cover vegetation for this site is well above the non-routine trigger level established in the LTCP.

6.2 ICS 2-Foot and 3-Foot Soil Covers

During the 2018 season, cover by a variety of weedy species composed only a small part of the total vegetation cover. Based on data from 15 samples, relative cover by weedy species was only about 2 percent. Average absolute live cover was about 57 percent. Average total cover remained high at 99 percent, with litter contributing about 42 percent cover. Cool season grasses, primarily western wheatgrass, provided an average cover of approximately 48 percent. Average cover by warm season grasses was about 7 percent. Cover by live vegetation in the 2-foot and 3-foot covers was similar to live vegetation cover on the ICS RCRA-equivalent covers.

6.2.1 Comparison to the Non-Routine Action Trigger Level

Total allowable live vegetation was estimated to be 57 percent, well above the non-routine action trigger level of 25 percent. The estimate for total ground cover was 99 percent, and corresponding bare ground was relatively low at 1 percent. The two-year running average for absolute total ground cover was 99 percent, well above the standard. The three-year running average for absolute total ground cover was 98 percent also well above the standard.

6.3 Sample Adequacy

Sample adequacy calculations were performed for each of the cover areas. The intent of the sample adequacy calculation is to determine whether sufficient samples have been gathered to be able to detect a 10 percent reduction in the mean with 90 percent confidence. Sample adequacy was calculated using the formula provided in SOP 002:

$$N_{\min} = t_{\alpha}^{2} s^{2} / (d\bar{x})^{2}$$

To ensure that the sample size is adequate, N_{min} must be less than, or equal to the number of transects sampled in the respective area. If N_{min} is greater than the number of transects sampled, additional vegetation transects need to be sampled until N_{min} becomes less than, or equal to the number of transects sampled, or all transect blocks within the respective area have been sampled, whichever comes first. Sample adequacy was calculated for total live vegetation only. The results of the sample adequacy calculations are provided in Table 6.3-1. Sample adequacy calculations indicated that variability was very low and that an acceptable number of samples were collected for all cover areas.

7.0 PERCOLATION MONITORING

The RCRA-equivalent covers use a network of lysimeters to monitor deep percolation. The ICS covers have 15 lysimeters, including three located on the SDT RCRA-Equivalent Cover, with an additional lysimeter located outside the southeast boundary of the SDT RCRA-Equivalent Cover. The SDT RCRA-Equivalent Cover lysimeters are equipped with tipping buckets that measure the volume of percolation that drains from the lysimeter pans. The tipping bucket data are stored in the SCMMS database with data from the moisture sensors described in Section 9.0. For the lysimeters located elsewhere on the ICS, the volume of percolation was directly measured by opening a valve, collecting the accumulated percolation water, and measuring the volume in the field.

The LTCP requires the quarterly submission of percolation monitoring results for all cover lysimeters to the Regulatory Agencies. These quarterly percolation submissions were historically combined with the quarterly SCMMS reports through the last quarter of FY17. O&M Change Notice (OCN)-LTCP-2017-001 (Navarro 2017b) documented the change in reporting frequency for the SCMMS from quarterly to annually. Starting in FY18, the quarterly submission of percolation monitoring results for all cover lysimeters were issued to the Regulatory Agencies independent of the SCMMS data and included three tables spanning six months of data. The three tables include monthly measurements, 9-month cumulative totals, and 12-month cumulative totals.

7.1 Percolation Compliance

Percolation is reported in millimeters, which is calculated by dividing the measured percolation volume by the area of the lysimeter pan, or 1,500 square feet (139.35 square meters). The volume of percolation measured monthly from each lysimeter is presented in Table 7.1-1. Table 7.1-2 presents rolling nine-month percolation totals for comparison to the non-routine action trigger level of 1.0 mm in nine months, and Table 7.1-3 presents twelve-month rolling totals for comparison to the compliance standard of 1.3 mm in 12 months. The compliance standard for percolation is the quantity of percolation that, if exceeded, would subject the Army to potential enforcement actions by the Regulatory Agencies. Enforcement of the compliance standard began on April 21, 2015.

As shown in Tables 7.1-2 and 7.1-3 all of the ICS lysimeters, except Lysimeter 014, were well below the non-routine action trigger level and the compliance standard for the entire year. A *Schedule for Investigation of Percolation Exceedance of Lysimeter 014 and Development of a Corrective Measures Plan of Action* was prepared and submitted to the Regulatory Agencies on October 4, 2018. Lysimeter 014 will be discussed further in the FY19 ICS ACR.

In previous reporting years, the SDT lysimeters and Lysimeter 004 were out of compliance and investigations were conducted to find the root cause. Beginning in June of 2018, the Cover Soil Field Investigation – Phase 2 was conducted for the SDT lysimeters and Lysimeter 004. Section 8.0 further discusses the Phase 2 investigation for the out of compliance SDT lysimeters and Lysimeter 004.

7.2 Percolation Exceedances

7.2.1 SDT Cover Lysimeters

During 2014, 2015, and 2016, the SDT lysimeters collected significant percolation quantities during the spring months. Enforcement of the percolation compliance standard began on April 21, 2015 and the standard was officially exceeded at Lysimeters 001 and 002 on May 21, 2015. Lysimeter 003 exceeded the percolation standard shortly thereafter on June 10, 2015. Another significant percolation event was documented for Lysimeter 001, 002, and 003 beginning on May 4, 2016. Since Lysimeter 003A is located off of the SDT RCRA-Equivalent Cover, the lysimeter was not subject to the compliance standard for percolation.

The Army conducted two phases of investigations to identify the root causes for the percolation exceedances for the SDT lysimeters. The first phase of the investigation, conducted in January of 2016, included evaluation of design and construction documentation and as-built test data,

topographic surveys of the cover surface, assessment of surface vegetation, and laboratory analysis of cover soil cores. The Army has reviewed the geotechnical and agronomic data gathered from the investigation and has also reviewed the root density analysis performed by the Department of Bioagricultural Sciences and Pest Management at Colorado State University. These data were consolidated into the *Integrated Cover System Cover Soil Testing Data Summary Report* (Navarro 2017a) which was issued on August 14, 2017.

The second phase of the investigation, conducted in FY18, consisted of dye testing the cover soil layer adjacent to Lysimeters 001, 002, 004, and 007, trenching the dye test areas for visual evaluation of visible preferential pathways, performance of geotechnical sampling and analysis (soil density field tests [via sand cone] and soil moisture content tests), and installation of piezometers in the low-lying areas of the Biota Barrier Material (BBM) runout of the SDT RCRA-Equivalent Cover and performance of water level monitoring. The installation of the piezometers did not occur in FY18 and will be discussed in the FY19 ICS ACR. The Cover Soil Field Investigation – Phase 2 is discussed in more detail in Section 8.0 of this report.

7.2.2 Lysimeter 004

Lysimeter 004 exceeded the percolation compliance standard in parts of 2016 and 2017. During the routine monthly inspection on June 8, 2016, OMC Cover Inspectors measured 177 liters of percolation water from Lysimeter 004, which equated to 1.27 mm. The June percolation value exceeded the non-routine action level, but did not exceed the compliance standard of 1.3 mm. The next routine monthly inspection was held on July 6, 2016. During the July inspection Lysimeter 004 produced 24 liters of additional percolation water. When the percolation volumes for June and July of 2016 were combined they equated to 1.56 mm, which exceeded the percolation compliance standard. The Regulatory Agencies were notified of the compliance standard exceedance by e-mail on July 6, 2016 (AECOM 2016).

Following the June 2016 inspection the Inspection Team examined the cover surface in the general area over the pan of Lysimeter 004 and did not identify any sub-standard conditions that could explain the sudden influx of percolation water. Inspectors continued investigating the cause of the percolation by using as-built survey data to locate the corners of the lysimeter pan and performed a more thorough inspection of the cover soil and vegetation on June 20, 2016. The investigation of the soil directly above, and adjacent to, the lysimeter pan did not identify any sub-standard conditions that could explain the sudden influx of percolation water. In addition, the Covers Manager asked the Groundwater Treatment Operations Manager to evaluate the condition of the CAT groundwater extraction well (well ID 36305), which is located up slope from the lysimeter. In 2010 the pitless adapter at the head of well 36305 had broken and released extracted groundwater near the cover surface. The well was repaired at the time, but the Covers Manager was concerned that the well may have failed again. Maintenance personnel inspected the well in June of 2016 and did not identify any evidence of leakage. The flow rate and line pressure in the extraction well conveyance piping were within normal parameters.

In June of 2017, Lysimeter 004 came back into compliance after the July 2016 percolation total did not contribute to the rolling 12-month compliance standard.

In 2015, the Army initiated an ongoing investigation to identify the root causes for the percolation exceedances at the SDT lysimeters, which also included Lysimeter 004. Therefore, a

substantial body of data was collected from the area adjacent to Lysimeter 004 including geotechnical, agronomic, topographic, and ecological data. This information was used to develop the second phase of the field investigation. Once the root cause has been determined, the Army and Shell will prepare a Corrective Measures Plan of Action in accordance with LTCP Section 3.6.2 for review and approval by the Regulatory Agencies.

Similar to the Phase 1 investigation, Lysimeter 004 was also included in the Phase 2 investigation that was conducted in FY18 and the details of this investigation are in Section 8.0 of this report.

7.2.3 Lysimeter 014

During a routine lysimeter inspection on September 5, 2018 the Inspection Team removed 221 liters of water from Lysimeter 014, which equated to 1.59 mm of percolation over the area of the 1,500 square-foot lysimeter pan. The OMC revisited Lysimeter 014 on September 24 and 25 and removed an additional 36 liters and four liters, respectively. The total volume of percolation water removed from Lysimeter 014 in September of 2018 was 261 liters, equating to 1.87 mm of percolation. When combined with the previous 11 months of percolation collected from Lysimeter 014, the total 12-month percolation measurement was 1.92 mm. The September 2018 measurement was a significant departure from the historical performance of Lysimeter 014.

On September 5, 2018 AECOM, on behalf of the Army and Shell, verbally notified the Regulatory Agencies of a percolation standard exceedance, as required by Section 3.6.1 of the LTCP. A follow-up email was sent to the Regulatory Agencies on the same date from the RMA OMC (Navarro 2018b) with additional information.

A *Schedule for Investigation of Percolation Exceedance of Lysimeter 014 and Development of a Corrective Measures Plan of Action* was transmitted to the Regulatory Agencies on October 4, 2018. The percolation exceedance of Lysimeter 014 will be further discussed in the FY19 ICS ACR.

8.0 COVER SOIL FIELD INVESTIGATION – PHASE 2

The objective of the Cover Soil Field Investigation – Phase 2 was intended to do three things: provide visual indications of preferential flow paths through the cover soil by using tracer dye, address shortcomings in the Phase 1 Field Investigation geotechnical data, and investigate the potential for standing water in the void space of the 50-foot BBM runout. Tracer dye tests, trenching, and geotechnical testing were performed near Lysimeters 001, 002, 004, and 007. The tracer dye testing, trenching, and geotechnical testing aspects of the field investigation were performed in July of 2018 in accordance with the *ICS Cover Soil Field Investigation – Phase 2 SAP* (Navarro 2018a). Piezometer installation is schedule for FY19. The results of the field investigation are presented in the *ICS Cover Soil Field Investigation – Phase 2 Data Summary Report* (Navarro 2018c), which is being prepared in parallel with this ACR.

The Phase 2 Investigation proved to be successful in visually identifying preferential flow paths in the cover soil near a moisture probe nest at Lysimeters 001 and 002. The dye testing and trenching at Lysimeter 001 was performed at Moisture Probe Nest 104 and for Lysimeter 002 was performed at Moisture Probe Nest 204. Nests 104 and 204 were removed during the Phase 2 Investigation and therefore are no longer in operation.

Based on the observations from the Cover Soil Field Investigation – Phase 2, it is clear that preferential pathways exist where nests of moisture probes were installed during construction of the SDT RCRA-Equivalent Cover. The vertical arrangement of moisture probes in the nests required the excavation of vertical faces and precluded scarification or sloping prior to backfilling, which could have mitigated the creation of preferential flow paths. The tracer dye tests showed consistent and significant preferential flow along these vertical faces, along moisture probe wiring, and along the probe leads that had been inserted into the undisturbed soil. Three such nests were installed over each of the SDT lysimeters. Therefore, it is reasonable to assume that preferential flow paths allowed abnormally high volumes of precipitation and surface flow to pass through the cover over the lysimeter pans, which led to artificially high percolation measurements by the lysimeters. The cover soil over the lysimeter pans is not representative of the SDT RCRA-Equivalent Cover at large and Lysimeters 001 and 002 cannot be used to accurately measure the cover's performance. Though Lysimeter 003 was not included in this investigation, the lysimeter also has moisture probe nests arranged over the lysimeter, and so the same recommendations are applicable.

The Army and Shell recommend using the available information and the consultative process with the Regulatory Agencies to develop a Corrective Measures Plan of Action (CMPA) in accordance with the LTCP Section 3.6.2. This CMPA should include steps to restore the soil cover conditions over the lysimeter pans and represent the larger SDT RCRA-Equivalent Cover, to the maximum extent possible.

While the soil near Lysimeter 004 did have evidence of preferential flow, the extent of the flow paths was not extensive and was most likely caused by shallow cracking near the soil surface. More importantly, the condition of the cover soil adjacent to Lysimeter 004 appeared to be representative of the ICS RCRA-equivalent covers in general, and no physical repairs are necessary at this time.

The Army and Shell recommend continued monitoring of Lysimeter 004 for evidence of excessive percolation.

9.0 SCMMS OPERATIONS AND MAINTENANCE

The SCMMS was operated and maintained in accordance with the *SDT Soil Remediation Project SCMMS O&M Plan*, Revision 2 (TtEC 2006). The *SCMMS O&M Plan* includes the SOPs for data collection and system maintenance activities, and guidelines for data reporting.

Reporting the SCMMS data supports the objectives of the *Resolution Agreement: Use of Moisture Sensors on Full-Scale RCRA-Equivalent Covers at the Rocky Mountain Arsenal*, April 8, 2004 (RVO 2004) (Moisture Probe Resolution Agreement). OCN-LTCP-2017-001 changed the reporting requirements for the SCMMS. Rather than being reported quarterly, data collected by the SCMMS will be provided to the Regulatory Agencies on an annual basis as part of the Annual Covers Report. The SCMMS data for FY18 are included in Appendix B.

The *Moisture Probe Resolution Agreement* requires the system to operate continuously for a period of time that includes seven full spring seasons following cover construction. This report includes data from the eleventh full spring season. The Army and Shell elected to continue operating the SCMMS beyond the agreed upon timeframe after unprecedented amounts of

percolation were experienced during the spring seasons of 2014, 2015, and 2016. The hope was that the SCMMS data may provide insight regarding soil cover conditions during the percolation events and contribute to the development of a corrective action.

The SCMMS data were evaluated as part of the percolation investigation documented in the *Integrated Cover System Cover Soil Testing Data Summary Report* (Navarro 2017a) and were also evaluated in the Cover Soil Field Investigation – Phase 2. The Army and Shell determined that the SCMMS data were of minimal value in regard to determining the root cause of the percolation. However, the Army and Shell agreed to continue operation of the SCMMS at the insistence of the Regulatory Agencies. The Army, Shell, and Regulatory Agencies agreed that moisture probe data may be useful in the future to demonstrate the effectiveness of the eventual corrective action. However, during the Cover Soil Field Investigation – Phase 2, it was determined that the moisture probes themselves were acting as the preferential flow paths for the excessive percolation. The Army and Shell will continue using the consultative process with the Regulatory Agencies to determine the usefulness and continuation of the moisture probe operation.

9.1 Data Collection and System Checks

The data presented in Appendix B were taken from a database created specifically to manage the SCMMS data. This database is administered by the Army's data management contractor, RMITS. OMC staff collected data by downloading data from the SCMMS, following the procedures in SOP-002-SDT. Data downloading was generally performed on a weekly basis. In addition to downloading data, the OMC staff also routinely checked the status of the datalogger and program by checking the program signature, battery voltage, date/time stamp, and other system parameters.

9.2 Data Review

After each download was completed, the Project Quality Assurance/Quality Control (QA/QC) Representative performed a QA/QC check on the data. Suspect readings, such as out of range readings, error messages, and data impacted by hardware malfunctions were flagged and reviewed. All flagged data were evaluated to determine whether the issue was an isolated occurrence or indication of a system error. System component failures are described in Section 9.3.

9.3 System Issues and Refinements

The following issues and refinements were encountered prior to, and during, this reporting period.

<u>Lysimeter 001, Moisture Probe Nests 4 and 5</u>: Probes 4 and 5 began recording erratically on October 11, 2017 at 1200. In March of 2018, OMC began trouble shooting the errors with help from the manufacturer Campbell Scientific and found some loose wires in the field equipment. After the loose wires were tightened, Moisture Probes 4 and 5 for all the Lysimeter 001 nests began recording data and the probes were deemed reliable on March 6, 2018 at 1800. Also, Campbell Scientific provided instructions on how to clear the dataloggers of errors and all of the SDT lysimeters were cleared of errors. The programs were tested after the errors were cleared and the system ran normally.

Lysimeter 001, Nest 104: During the Cover Soil Field Investigation – Phase 2, the cables for moisture probe nests 104 were potholed and cut on June 26, 2018. The final readings for this nest were recorded on June 26, 2018 0600.

Lysimeter 002, Nest 104: During the Cover Soil Field Investigation – Phase 2, the cables for moisture probe nests 204 were potholed and cut on June 26, 2018. The final readings for this nest were recorded on June 26, 2018 0600.

Lysimeter 003A, Moisture Probe Nest 1: Probes 3 and 6 did not operate properly for the duration of the reporting period.

Lysimeter 003A, Moisture Probe Nest 4: Probes 1, 2, and 6 did not operate properly for the duration of the reporting period. Probes 4 and 7 have not operated properly since August 8, 2009, but beginning on July 12, 2016, these probes began recording data and continued through this reporting period. However, the values recorded by these probes do not appear to be within the expected range for their respective soil horizons. Therefore, the data that was recorded from these probes was flagged in the database due to unreliability.

Routine Battery Replacement: In October of 2017, OMC personnel replaced all of the 12 volt batteries in the SDT SCMMS panels. The battery was also changed in the panel in Building 132 that serves as a middle point between the SCMMS panels and the SCMMS computer station.

10.0 ROUTINE AND NON-ROUTINE ACTIONS

10.1 Routine Actions

Routine maintenance and repairs were performed on ICS and were intended to ensure that the cover continues to function as designed. Routine maintenance and repair actions were identified during inspections and are discussed in Section 4.0 of this report. Figure 4.0-1 illustrates the locations of routine maintenance and repair activities performed on ICS during FY18. Appendix E includes Contractor Daily Quality Control Reports that describe the work performed.

10.2 Non-Routine Actions

The implementation of non-routine actions is described in the LTCP. The LTCP provides criteria for non-routine actions, and a mechanism for consultation between the parties and documentation of the consultative outcome. Each time a non-routine action was identified a Non-Routine Action Plan (NRAP) was prepared to document the substandard condition, the actions that will be carried out to remedy the condition, consultation between the parties, and concurrence on the proposed action. There were no NRAPs prepared for the ICS during FY18.

11.0 RECOMMENDATIONS AND CORRECTIVE MEASURES

Inspections and assessments performed during FY18 produced the following recommendations for FY19:

- The Army and Shell recommend using the available information collected over the course of two field investigations and the consultative process with the Regulatory Agencies to develop a CMPA for the SDT RCRA-Equivalent Cover. This CMPA should attempt to restore the soil cover conditions over the lysimeter pans and represent the larger SDT RCRA-Equivalent Cover, to the maximum extent possible.

- Install piezometers in the low-lying areas of the BBM runout of the SDT RCRA-Equivalent Cover and perform water level monitoring.
- Finalize a *Schedule for Investigation of Percolation Exceedance of Lysimeter 014 and Development of a Corrective Measures Plan of Action.*
- The site should be examined for weeds throughout FY19. Occurrences of cheatgrass, Canada thistle and other noxious weeds should be spot sprayed.
- The site should continue to be examined for erosion rills or gullies, ponding areas, excessive tire tracks and ruts, burrowing animal holes, and localized settlement.

The Army intends to perform corrective measures to address percolation performance of the excessive percolation at Lysimeters 001, 002, 003, 004, and 014 once the root cause(s) have been determined and the Regulatory Agencies approve the proposed corrective measures.

12.0 FY18 COSTS AND FY19 BUDGETS

Cost incurred performing Interim O&M of the ICS AMA during FY18, including inspections, repairs, and maintenance, was $117,251. A complete budget for FY19 has not been approved as of the issuance of this report. However, the FY18 budget is estimated to be approximately $150,301.

13.0 REFERENCES

AECOM

2016 (Jul 6) *Email sent by Kelly Cable, Subject: Lysimeter 4 Percolation Notification*

Navarro (Navarro Research and Engineering, Inc.)

2014 (Nov 14) *Annual Covers Report for Integrated Cover System 2014.* Revision 0.

2017 (Aug 14) *Integrated Cover System Cover Soil Testing Data Summary Report.* Revision 0.

2017a (Sep 28) *OCN-LTCP-2017-001.*

2018a (Jun 6) *Integrated Cover System Cover Soil Field Investigation – Phase 2 Sampling and Analysis Plan.* Revision 0.

2018b (Sep 8) *Email sent by Michael W. Jones, Subject: Agency Notification for Percolation Standard Exceedance at Lysimeter 014.*

2018c (Oct 17) *Integrated Cover System Cover Soil Field Investigation – Phase 2 Data Summary Report.* Revision A.

RVO (Remediation Venture Office for Rocky Mountain Arsenal)

2004 (Apr 8) *Resolution Agreement Use of Moisture Sensors on Full-Scale RCRA-Equivalent Covers at the Rocky Mountain Arsenal.*

TtEC (Tetra Tech EC Inc.)

2006 (Jun 15) *SDT Soil Remediation Project SCMMS O&M Plan.* Revision 2.

2011 (Sep 29) *RCRA-Equivalent, 2-, and 3-Foot Covers Long-Term Care Plan.* Revision 2.

TABLES

Table 5.0-1: Soil Cover Thickness Loss

ICS Monument No.	Loss (in.) April 10, 2018	Loss (in.) September 19, 2018	Comments
ER01	0.25	0.50	
ER02	1.00	0.75	
ER03	0.00	0.00	
ER04	2.00	1.75	
ER05	2.50	2.50	
ER06	1.25	1.50	
ER07	0.00	0.50	
ER08	2.50	2.00	
ER09	1.00	1.00	
ER10	1.00	1.25	
ER11	1.00	1.25	
ER12	1.00	0.75	
ER13	1.50	1.25	
ER14	1.00	1.00	
ER15	0.00	0.00	
ER16	1.50	1.25	
ER17	0.00	0.00	
ER18	0.00	0.00	
ER19	0.00	0.00	Carsonite marker needs to be replaced
ER20	2.00	2.00	
ER21	1.00	0.25	Needs ER cap glued back on
ER22	1.25	1.50	
ER23	0.50	0.00	
ER24	0.00	0.00	
ER25	1.00	1.75	
ER26	0.00	0.00	
ER27	1.00	1.50	
ER28	1.50	1.75	
ER29	2.00	2.25	
ER30	2.50	2.50	
ER31	1.75	2.00	
ER32	0.00	0.00	
ER33	0.50	1.25	
ER34	1.50	1.50	
ER35	2.00	1.50	
ER36	3.00	1.50	Sits in a depression
ER37	2.00	2.25	

Table 5.0-1: Soil Cover Thickness Loss

ICS Monument No.	Loss (in.) April 10, 2018	Loss (in.) September 19, 2018	Comments
ER38	2.00	2.00	
ER39	0.50	0.00	
ER40	1.00	1.50	
ER41	2.00	2.50	
ER42	0.50	0.00	
ER43	1.50	1.75	
ER44	2.00	2.00	
ER45	1.25	1.00	
ER46	3.00	3.00	Neeeds additional soil around monument
ER47	2.00	2.25	
ER48	1.00	1.50	
ER49	1.00	1.00	
ER50	1.00	0.25	
ER51	0.00	0.00	
ER52	0.00	0.25	
ER53	1.00	1.25	
ER54	0.00	0.00	
ER55	1.00	1.25	
ER56	1.00	1.00	
ER57	0.50	0.00	
ER58	0.50	0.75	
ER59	1.00	0.75	
ER60	1.75	1.75	
ER61	0.25	0.00	
ER62	0.25	0.75	
ER63	1.75	1.75	
ER64	1.50	1.00	
ER65	3.00	1.75	
ER66	1.25	1.50	
ER67	0.00	0.75	
ER68	1.00	1.00	
ER69	1.00	1.00	
ER70	0.00	0.00	
ER71	1.00	0.75	
ER72	1.75	2.00	
ER73	1.50	1.75	
ER74	0.00	0.00	

Table 5.0-1: Soil Cover Thickness Loss

ICS Monument No.	Loss (in.) April 10, 2018	Loss (in.) September 19, 2018	Comments
ER75	1.00	0.00	
ER76	1.75	2.50	Needs additional soil around monument
ER77	1.00	1.25	
ER78	1.00	1.50	
ER79	0.00	0.50	
ER80	1.00	0.75	
ER81	1.00	1.00	
ER82	0.75	0.75	
ER83	0.00	0.25	
ER84	1.50	1.50	
ER85	1.00	1.00	
ER86	0.00	0.00	Sits in a depression
ER87	0.00	0.00	
ER88	1.25	1.50	
ER89	1.50	1.25	
ER90	2.50	2.50	
ER91	1.25	1.25	
ER92	0.50	0.00	

Table 6.0-1: 2018 Vegetation Performance Assessment Summary

Performance Criterion and Evaluation	2-Foot and 3-Foot Covers (Note 1)	ICS RCRA-Equivalent Cover
Total Absolute Ground Cover	98.90%	96.70%
Allowable Total Absolute Live Vegetation Cover	57.10%	55.80%
Vegetation Performance Standard for Total Live Vegetation	≥ 25%	≥ 25%
Is Vegetation Performance Standard met? (Enforcement started in fall 2015.)	Yes	Yes
Two Year Running Average for Total Absolute Ground Cover	98.80%	95.80%
Vegetation Performance Standard for Two Year Running Average	≥ 50%	≥ 50%
Is Vegetation Performance Standard met? (Enforcement started in fall 2016.)	Yes	Yes
Three Year Running Average for Total Absolute Ground Cover	97.70%	93.50%
Vegetation Performance Standard for Three Year Running Average	≥ 67%	≥ 67%
Is Vegetation Performance Standard met? (Enforcement started in fall 2017.)	Yes	Yes
Relative Weed Cover	2.10%	0.30%
Relative Allowable Weed Cover	N/A (Note 3)	≤ 10%
Calculate Total Live Vegetation without the weed fraction? (Note 2)	N/A (Note 3)	No

Note 1: For 2-Foot and 3-Foot soil covers, vegetation performance criteria function as Non-Routine Action Trigger Levels, not compliance standards.

Note 2: The relative weed cover is less than 10 percent, therefore, subtracting all but 10 percent of the total live vegetation cover fraction that is comprised of weeds does not affect the Total Live Vegetation calculation. The Total Live Vegetation values are within the Non-Routine Action Trigger Levels.

Note 3: The relative weed fraction does not affect vegetation compliance or non-routine actions on the 2-Foot and 3-Foot soil covers.

Table 6.3-1: Sample Adequacy Results

Cover Area	Sample Size (n)	Minimum Sample Size total live cover (N_{min})
ICS RCRA-Equivalent Covers	30	0.2
ICS 2-Ft and 3-Ft Soil Covers	15	0.04

Note: Based on absolute total live vegetation cover

Table 7.1-1: Monthly Percolation Measurements

Lysimeter No.	Monthly Percolation Measurement (ml)											
	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
Lysimeter 001	7,876	192	0	0	0	0	0	0	0	4,772	7,222	5,690
Lysimeter 002	0	0	0	0	0	0	0	0	0	0	0	0
Lysimeter 003	231	0	0	0	0	0	0	0	0	0	0	0
Lysimeter 003A	5,427	144	8	0	0	0	0	0	0	0	0	0
Lysimeter 004	1,000	Trace	Trace	0	0	0	0	0	0	0	1,000	Trace
Lysimeter 005	11,500	1,000	Trace	0	0	0	0	0	0	0	4,000	11,000
Lysimeter 006	0	Trace	Trace	0	0	0	0	0	0	0	0	0
Lysimeter 007	0	Trace	Trace	0	0	0	0	0	0	0	0	0
Lysimeter 008	500	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	500	3,000	Trace
Lysimeter 009	0	Trace	Trace	0	0	0	0	0	0	0	0	0
Lysimeter 010	0	Trace	Trace	0	0	0	0	0	0	0	0	0
Lysimeter 011	Trace	Trace	0	Trace	0	0	0	0	0	0	0	Trace
Lysimeter 012	0	0	Trace	0	0	0	0	0	0	0	0	0
Lysimeter 013	3,000	Trace	Trace	0	Trace	0	0	0	0	0	4,000	3,000
Lysimeter 014	2,000	Trace	Trace	0	Trace	0	0	0	0	0	4,000	261,000
Lysimeter 015	1,000	Trace	Trace	0	0	0	0	0	0	1,000	6,000	0

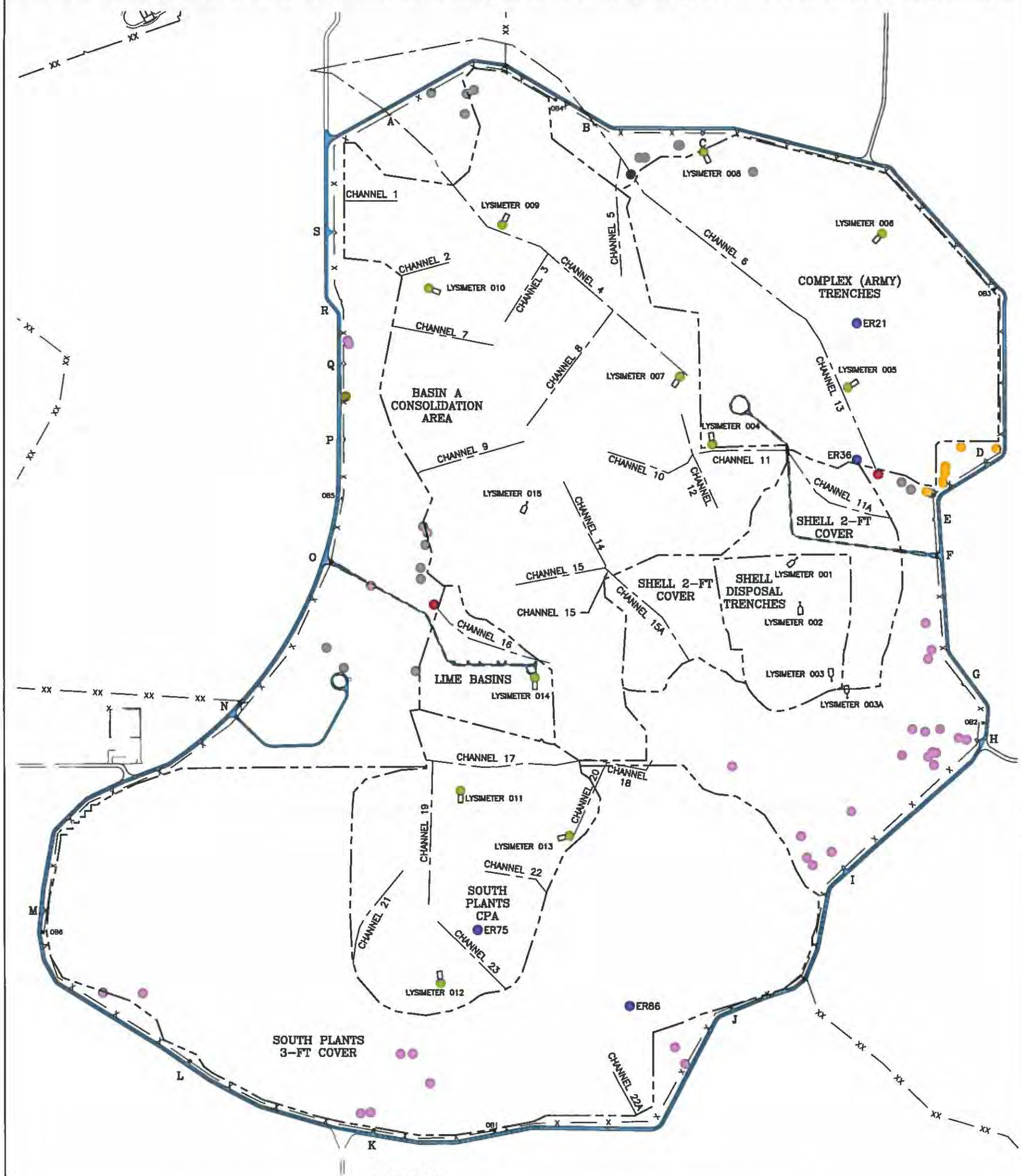
Table 7.1-2: Rolling Nine-Month Percolation Totals

Lysimeter No.	Rolling Nine-Month Percolation Total (mm)											
	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
Lysimeter 001	0.40	0.40	0.40	0.40	0.40	0.40	0.37	0.21	0.06	0.04	0.09	0.14
Lysimeter 002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 003	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.00	0.00	0.00	0.00
Lysimeter 003A	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.16	0.04	0.00	0.00	0.00
Lysimeter 004	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.00	0.01	0.01
Lysimeter 005	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.20	0.09	0.01	0.03	0.11
Lysimeter 006	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 008	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.00	0.00	0.03	0.03
Lysimeter 009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 013	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.05	0.02	0.00	0.03	0.05
Lysimeter 014	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.00	0.03	1.90
Lysimeter 015	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.02	0.01	0.01	0.05	0.05

Table 7.1-3: Rolling Twelve-Month Percolation Totals

Lysimeter No.	Rolling Twelve-Month Percolation Total (mm)											
	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
Lysimeter 001	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.41	0.29	0.18
Lysimeter 002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 003	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.00
Lysimeter 003A	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.16	0.04
Lysimeter 004	0.07	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01
Lysimeter 005	0.28	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.23	0.20
Lysimeter 006	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 008	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.03
Lysimeter 009	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 010	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysimeter 013	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07
Lysimeter 014	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.05	0.05	1.92
Lysimeter 015	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.07	0.07	0.06

FIGURE



LEGEND

- COVER BOUNDARY
- INTERIOR ACCESS ROAD
- PERIMETER FENCE
- USFWS BISON PASTURE FENCE
- PERIMETER ACCESS ROAD (SEE NOTE 1)
- LYSIMETER
- CHANNEL FLOW LINE
- OB1 OBELISK
- K LABELED GATES AND CATTLE GUARDS
- PERIMETER FENCE MAINTENANCE
- LYSIMETER MAINTENANCE
- CHEATGRASS
- REPAIRED EROSION MONUMENTS
- REPAIRED ANIMAL HOLES
- GROUND HERBICIDE
- REPAIRED CHANNEL
- REPAIRED DIFFERENTIAL SETTLEMENT AND OTHER CONDITIONS THAT COULD INTERRUPT COVER DRAINAGE

COLORADO STATE PLANE

NTS

NOTE 1: THE OUTSIDE SHOULDER OF THE PERIMETER ACCESS ROAD DEFINES THE ARMY MAINTAINED AREA BOUNDARY (AMA).
NOTE 2: TUMBLEWEEDS WERE REMOVED FROM THE ICS PERIMETER FENCE.

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

NAVARRO
Research and Engineering, Inc.

PROJECT NAME
ANNUAL COVERS REPORT FOR INTEGRATED COVER SYSTEM 2018

TITLE
ICS ROUTINE MAINTENANCE ACTIVITIES MAP

CAD FILE:	DATE	FIGURE NUMBER
ICS FIGURE 4.0-1.DWG	10.29.18	4.0-1

S:\G PROJECTS\ANNUAL COVERS REPORT 2018 - OCTOBER\

APPENDICES

(All on CD)

A	Precipitation Data (October 1, 2017 through September 30, 2018)
B	SCMMS Data (October 1, 2017 through September 30, 2018)
C	2018 Vegetation Performance Assessment Documentation
D	Cover Inspection Documentation (October 1, 2017 through September 30, 2018)
E	Maintenance and Repair Documentation (October 1, 2017 through September 30, 2018)