

Volume II contains a set of conceptual design drawings for the excavation, lining, filling, final closure design and details for the lateral expansion areas. Drawing numbers referred to in this section are contained in Volume II. All components for lateral expansion and the final cover for the existing landfill were designed in accordance with Federal Environmental Protecting Agency (EPA) requirements specified in Subtitle D 40 CFR Part 258 (Subtitle D) and the Arizona Revised Statutes, Chapter 4, Section 49-700.

8.1 FILL PROGRESSION

8.1.1 Landfilling the Existing Footprint to Completion

The existing footprint of the Cinder Lake Landfill covers 110 acres (Drawing 2). Additionally, two lined areas, one on the south and one on the east (in the expansion area) of the existing footprint, are planned and will cover an additional 136 acres. Waste material will continue to be placed within the existing, unlined landfill footprint in a series of three phases (A, B, and C). The landfill layout and sequencing is presented on Drawing 5.

Area A at the northeast portion of the site will be constructed first, followed by Areas B and C. Depending on location, 4 to 9 more lifts, approximately 10-feet in height, will be constructed to completely fill the existing landfill footprint. Each area will be closed as it is completed. The configuration for this existing area is presently designed with final elevations approximately 40 feet above the highest natural grade (Drawing 4) on the north side of the existing landfill. Daily, intermediate, and final cover material for these areas will be excavated from the proposed expansion Area E (Drawing 3).

Areas A, B and C have a joint estimated refuse capacity of approximately 7.3 million cubic yards (cy) (Assuming a 3:1 refuse to soil ratio). Based on the waste receiving rates presented in Table 3-4, it is projected that these areas will be completed in 2017.

8.1.2 Lateral Expansion

The lined lateral expansion will consist of two areas shown as Areas D and E on Drawing 5. These areas will have geosynthetic composite liners and are designed to be in compliance with the requirements specified in Subtitle D and the Arizona Solid Waste Landfill Rule as amended July 28, 1997. Each of these areas are further divided into cells. There are 2 cells in Area D and 8 cells in Area E. Each cell will provide between 5 and 7 years of capacity. The layout for the construction of Cells E-1 and E-2, including staging and stockpile areas, is shown on Drawing 6. Standard details and cross sections for a typical cell is presented on Drawing 10.

The size and capacity of each cell is estimated as follows:

| Area | Size in Acres | Capacity in Cubic Yards |
|------|---------------|-------------------------|
| D | 30 | 3.8 million |
| E | 107 | 14.1 million |

Based on the waste receiving rates presented in Table 3-4 it is projected that Area D will be completed in 2024 and Area E in 2042. It should be noted that currently construction of Area D-1's liner system is projected to begin in 2018. However, the City may begin construction within this area prior to this time. In either case, as agreed during a meeting between ADEQ and the City on December 5, 1996, the City will submit detailed plans and specifications for the new cell in the lateral expansion to ADEQ for review and approval prior to the installation of the liner and leachate collection system.

8.2 STORM WATER CONTROL

Surface water will be drained from the site to minimize ponding. Temporary drainage ditches or dikes will be constructed adjacent to working areas and excavations to prevent ponding and surface runoff from discharging into the landfilled areas. The storm water drainage design is shown on Drawing 8.

As the overall landfill footprint acreage increases so will the operating grades directing surface water to run off of the landfill surfaces to the perimeter conveyance ditches. These ditches will likely be fabric and grass or cinder lined. These ditches, will drain through culverts, under the perimeter and access roads, to several storm water infiltration areas located around the perimeter of the site.

Drainage benches on the landfill slope will be constructed to divert storm water to corrugated pipes that will drain to the perimeter ditches as the fill height rises over 50 feet in elevation above existing grade. The top of the landfill is designed to have a series of ridges or fingers to maximize fill volume while minimizing storm water drainage flow lengths and directing storm water off of the landfill as quickly as possible. The top deck drains away from the ridgeline at a 5% grade. Lined berms/ditches will be constructed to intercept water run off before it reaches critical (erosional) velocities, on the flatter areas of the landfill surfaces. The berms/ditches will be spaced approximately 500 feet apart. These berms/ditches will empty into corrugated pipes at the top edge of the 3:1 slopes.

All drainage ditches, berms/ditches and infiltration areas were sized conservatively. The design storm event was a 100-year, 24-hour storm. Data from Arizona State University Climatology Department indicates that the precipitation from a 100-year, 24-hour storm event for Flagstaff is 4.60 inches. Because the topography surrounding the site is relatively flat and the surface soils are very permeable, runoff originating offsite is not expected to enter the perimeter ditches. Details are provided on Drawing 12 and the calculations are provided in Appendix E.

8.3 CINDER STOCKPILE AREAS

Soils excavated from the Area E will be used as daily and intermediate cover. The upper 5 feet of soil in Area E is generally cinder and will be removed and stockpiled for use as the top layer in the final closure cap. The soil underlying the cinder will be excavated as needed. Therefore no stockpiling of this material, other than daily to weekly placement near operating areas, is anticipated. It should be noted that cinders are currently not used onsite as cover material as they are used for winter weather road application. The location of the proposed cinder stockpile

area is presented on Drawing 4. When this area is no longer needed for stockpile purposes a small potential lateral expansion as shown on Drawing 8 may be proposed. If it becomes cost effective to develop this area in the future, plans and specifications will be prepared and submitted to ADEQ for review and approval prior to construction.

8.4 LINER AND LEACHATE COLLECTION AND REMOVAL SYSTEMS

A geosynthetic composite liner and leachate collection and removal system (LCRS) will be installed in the landfill expansion areas (Phases D and E). A prescriptive Subtitle D liner would include a 60-mil high density polyethylene (HDPE) flexible membrane liner (FML) on top of two-feet of compacted soil with a hydraulic conductivity no greater than 1×10^{-7} cm/sec. An alternative liner incorporating a geosynthetic clay liner (GCL) in lieu of the clay layer is proposed for use at the site. The liner system will be sloped to facilitate leachate drainage to the LCRS collection pipes. Section 8.12 contains the demonstration for the alternative liner design (GCL liner).

The subgrade of the expansion area will be cleaned of stakes, debris, and any other materials that may puncture the GCL and FML liners. In addition, the subgrade soils moisture content should be minimal to prevent overhydration of the bentonite within the GCL. During a recent geotechnical investigation by Woodward-Clyde (1997), evidence of perched groundwater conditions within the cinder unit toward the southeast portion of the expansion area was found in boring WC-13 (Drawing 2). The City is planning on installing 3 to 6 piezometers in the expansion area near WC-13. These piezometers will allow water levels to be monitored over an extended period of time, and will allow sampling and analysis of perched groundwater if significant quantities are present. It is projected that soil for daily and intermediate cover will be excavated from the soil layer below the cinder layer several years prior to proposed liner construction in this area. The piezometer results will then be verified during the excavation of cover materials from this portion of the expansion area. If perched water conditions are observed, subdrains will be added to the design of the affected portions of the lateral expansion to limit hydration of the GCL. Typical subdrain details are shown in Figure 8-1. Final details of these subdrains, if necessary, will be provided to ADEQ for review and approval in the plans and specifications for the corresponding cell.

The LCRS will consist of a 2-foot sand layer on top of the FML. At the designed low points of the liner, a gravel filled sump with piping and filter fabric will be installed to collect and remove leachate. Leachate will be pumped to either a temporary storage tank located near the sump clean out or through a dedicated force main to storage tanks located at strategic points around the southern edge of the landfill (see Drawing 7).

The Hydrogeologic Evaluation of Landfill Performance (HELP) computer model (version 3.05) was used to estimate maximum depth of leachate above the liner. The HELP model uses equations developed by McEnroe (1993) to calculate this depth. The LCRS must be designed to prevent greater than 30 cm depth of leachate above the liner. A detailed discussion of the HELP model, parameters selected, and the calculated results is presented in Section 9. Details for the liner and LCRS are shown on Drawings 10 and 11.

Prior to finalizing the construction plans and specifications for Cell E-1 (anticipated in 2024) the City will determine whether to use temporary storage tanks located at the leachate sump clean-out or to install a more central leachate storage facility with a leachate force main along the southern perimeter of the expansion. A leachate management plan will be prepared and submitted to the ADEQ for review and approval prior to implementation. The advantage to temporary storage tanks would be to capture relatively high volumes of “leachate” collected in the early stages of waste fill. As the elevation of waste over the LCRS system increases, the leachate quantities collected should decrease. In semi-arid environments, such as that where the Cinder Lake Landfill is located, the quantities of leachate generated in each cell could be very minimal. The temporary storage tanks can be moved to service the newer cells once and if they are no longer required to service the sump which they originally serviced. This system of temporary tanks would add flexibility to the leachate management system.

Leachate sump pumps will be automatically switched on and off by level controllers. Their discharge will be sent to the temporary tanks or through the force main to permanent storage tanks.

At this time it is anticipated that the collected leachate will be used for on-site dust control. Leachate storage tank sizing will be developed during the construction-level design for each lined cell and will be designed to allow leachate storage during the wet months of the year. Alternatively, leachate treatment options could also be evaluated.

8.5 DAILY AND INTERMEDIATE COVER

Soils excavated from Area E, below the top cinder layer, will be used for daily and intermediate cover. This area will be excavated to conform closely to the excavation plan detailed in Drawing 3. The excavation plan was developed based on the maximum depth of rippable rock in the expansion areas determined by a geotechnical investigation conducted in 1997 (Woodward-Clyde, 1997). Generally, the top 5 feet of the soils found in Area E are cinder which can be set aside and used as a portion of the landfill's final cover cap. The underlying soils can be excavated as needed on a daily or weekly basis, to minimize handling of the soil. Scraper access roads from the excavation area to the active refuse disposal working face will be constructed on an as needed basis.

Based on preliminary calculations for the proposed landfill expansion, the site will have a deficit of daily/intermediate cover of 1 to 3 million cubic yards assuming no ADC usage. This quantity was estimated based on the City's present practice of placing cover soil at a refuse to soil ratio of 3:1. The City can make up for the soil shortage with a combination of the following alternatives: 1) using ADC materials (see Section 7.1.6.2 for discussion), 2) being more efficient with its soil usage (i.e., increasing the refuse to soil ratio) and 3) importing needed soils from nearby borrow sources. Since the site capacity will allow refuse disposal operations for decades, it is anticipated that the City will be able to implement one or more of these options to balance soil needs for CLL.

Cinder stockpile areas will most likely be within the existing landfill footprint for the closure of Areas A and B; in Area D for closure of Area C; within Area C or E for Area D, and in Area E and the footprint shown in Drawing 4 for Area E.

8.6 LANDFILL FINAL COVER

8.6.1 Lined Expansion Area

The final cover details are shown on Drawing 10. The final cover for the lined lateral expansion areas will at a minimum include (from the top, down):

- An erosion layer consisting of 6 inches of topsoil or cinders
- A 12-inch of random fill (or cinders) layer
- A 6-inch sand drain layer (or cinders)
- A 60-mil HDPE or other appropriate flexible membrane liner (FML)
- A GCL layer
- A minimum of a 18-inch intermediate foundation layer (intermediate cover)

An alternative monolithic cap may be proposed for the lined expansion area when this cap is to be constructed in the distant future. See Section 8-13 for details regarding this option.

8.6.2 Existing Unlined Landfill

The final cover configuration for the existing landfill footprint will have a permeability of no greater than 1×10^{-5} cm/sec and will include:

- An erosion layer consisting of 6 inches of topsoil (or cinders)
- A 12-inch of random fill (or cinders) layer
- A 6-inch sand drain (or cinders) layer, draining to a storm water collection system
- A 60-mil HDPE or other appropriate flexible membrane liner (FML)
- A minimum of an 18-inch foundation layer

The top of the final cover will be installed and maintained with a 3 to 5 percent slope. The side slope will have a maximum grade of 3:1 and will intersect with a storm water collection system around the perimeter of the site.

8.7 LANDFILL GAS (LFG) COLLECTION SYSTEM

8.7.1 LFG Generation Modeling

The primary purpose of landfill gas (LFG) production modeling is to establish a basis for the LFG system design so that the system will be able to extract LFG as required to control perimeter LFG migration and surface emissions. Due to the empirical nature of the model the results cannot be guaranteed. However, the method as described in this section has proven to be effective for similar projects and is expected to result in an LFG collection system that will likely meet the needs of the Cinder Lake Landfill.

8.7.1.1 Refuse Decomposition

Refuse decomposes in two stages. The first stage is aerobic, resulting in the formation of organic fatty acids. The second stage is anaerobic and is characterized by methanogenic bacteria, which decompose the organic fatty acids into carbon dioxide and methane. Because the generation of methane is indicative of second-stage refuse decomposition, methane gas can be used as the representative gas for LFG generation prediction.

Decomposition depends on many factors, including temperature, pH, moisture content, refuse size, refuse density, refuse age, quantity and quality of nutrients, and the presence of inhibitors. These factors are different for every landfill, and the extent of their impact is unknown. Forecasting methane generation is difficult because of these varying conditions and their unknown impact on methane generation rate. Even under similar conditions, the rate of methane production varies.

8.7.1.2 Methods

Numerous LFG models have been developed to help predict the rate of LFG generation. These models use different approaches and assumptions to predict the LFG generation rate. The most widely accepted model is based on a 1st order decay equation developed for the Scholl Canyon Landfill in Southern California, called the Scholl Canyon Model. The EPA, other agencies, and experts in the field base their gas production models on this equation. The EPA's gas production model was used to estimate LFG production at CLL.

8.7.1.3 Estimation of Refuse Volume

Estimating the annual refuse disposals rates was required to predict the potential LFG production rates so that the gas collection system could be generally sized. The annual disposal rate for the landfill from initial operation through 1985 was estimated by Woodward-Clyde (1997). Actual disposal rates were used between 1985 through 1997. Projected rates were used for 1998 through completion.

8.7.1.4 Estimation of Landfill Gas Production Rate

The computer program Energy Project Landfill Gas Utilization Software (E-Plus), developed by the EPA, was used to estimate the LFG production rate based on the volume and type of refuse. This computer model estimates annual LFG production over any time period specified by the user. Total LFG production is estimated by doubling the estimation of methane generation (the LFG is assumed to be half methane and half carbon dioxide). Methane generation is estimated using two parameters: L_0 , the potential methane generation capacity of the refuse, and k , the methane generation rate constant, which accounts for how quickly the methane generation rate decreases once it reaches its peak rate. The methane generation rate is assumed to be at its peak upon closure of the landfill or final placement of waste at the site. Default values from the model were used to estimate the LFG production rate. The peak LFG generation is anticipated to be 715 million cubic feet/year (or 1,200 cfm) in the year 2042. LFG generation modeling results are presented in Appendix F.

8.7.2 Design of LFG System

The detailed design of the LFG collection system will be developed and installed when NMOC emissions are estimated to exceed the NSPS threshold of 50 Mg per year (approximately 2005). This section provides conceptual design features for the LFG system based on current (1998) practices. It is expected that these concepts will be modified and updated prior to development of construction plans and specifications for the LFG system components. It is expected that horizontal collection trenches as shown in Drawings 9 and 13 will be constructed as the landfill progresses. As required by regulation, detailed LFG system plans and specifications to complete the system will be submitted to ADEQ for review and approval prior to construction.

8.7.2.1 Horizontal LFG Collection Pipes

The LFG collection system conceptual design includes perforated horizontal collection pipes placed across two elevations of refuse fill (See Drawing 9). These pipes would surface from the refuse mass at elevations 6,650 feet and 6,690 feet, vertical difference of 40 feet. They are spaced 250 feet apart, horizontally, at each elevation. They are staggered by 125 feet from one layer to the next to provide more efficient collection. Horizontal collectors limit operational interference by the LFG collection system for landfill operators (especially at landfills that have large acreages), where vertical wells spaced at typical 150 to 200 foot spacings can interfere with landfill disposal operations. LFG trenches can be easily installed by the landfill operators as the landfill progresses. However, as the LFG system is installed and operated over time, it may become necessary to reduce LFG emissions from specific areas. Vertical wells can be installed to augment the horizontal trenches collection in these areas.

8.7.2.2 LFG Header Piping

Lateral piping will be used to connect each horizontal LFG collection trench to the Main LFG Header pipe that surrounds the landfill footprint (See Drawing 9). The header piping can be placed above or below grade, depending on the City's preferences for general landfill operations, system monitoring maintenance and operation. HDPE pipe is the recommended pipe material due to its durability and tight seals at each pipe joint.

Condensate traps are located at design low points along the header alignment. These traps empty condensate into sumps, that will automatically pump condensate to predesigned locations typically at the LFG disposal area or leachate storage tanks, for storage and disposal. The sump pumps can be powered by electricity or compressed air. The condensate may be used for dust control, as approved by the ADEQ.

8.7.2.3 LFG Disposal Options

The LFG disposal facility will likely comprise two or more blowers and two or more flares. Alternatively, LFG can be used as a fuel in natural gas fired turbines or internal combustion engines for electrical power generation. The City may consider these power generation

alternatives at a later time. Other energy utilization options for LFG disposal can include; clean-up and sale to displace industrial natural gas, or process steam generation.

8.8 STABILITY ANALYSES AND SEISMIC HAZARD EVALUATION

This section summarizes the results of an evaluation of stability and seismically-induced deformation of the proposed expansion at CLL. The analyses have focused primarily on Cell 1 of Area E of the landfill expansion. This area was evaluated to be the most critical because of the presence of an unbuttressed leading edge of the landfill and underlying liner. A detailed discussion of the seismotectonic setting, site conditions and analytical methodology used is contained in Appendix G.

Based on the stability analyses performed, the presently proposed 3H:1V landfill slopes will be stable under static loading conditions. The stability of the final cover will depend on the strengths of the liner materials selected. Parametric analyses were performed to evaluate the strengths required to achieve a factor of safety of at least 1.5. The results of these analyses (see Appendix G) indicate that strengths (combination of cohesion and friction) that are typical of liner materials will produce a stable final cover under static loading. A laboratory testing program to confirm material properties will be conducted once these cover materials are selected.

40 CFR §258.14(b) requires that the seismic design of a landfill be based on a probabilistic peak horizontal acceleration assuming a 10% exceedance in 250 years. A design earthquake of moment magnitude (M_w) 6.5 with a peak horizontal acceleration of 0.30 was selected based on a probabilistic and deterministic evaluation as discussed in Appendix G. The Newmark method of analysis was used to evaluate the seismic deformations of the landfill mass and final cover induced by the design event. These analyses indicate that a potential failure surface that encompasses the base liner may deform 1 to 2 inches during the design level earthquake. The ground motions could be amplified through the refuse mass. Deformations of the final cover could be on the order of 1 foot.

Because of the susceptibility of the liner to potential seismically induced deformation during staged filling, care should be taken by the landfill operator to minimize shear loads on the liner. This can be achieved by minimizing the ratio of the height to width of the refuse pile during filling. In order to minimize liner shear loads during landfilling, the base width of the refuse should be at least 3 times greater than refuse height. The base width of the refuse is the length of refuse in the direction of potential sliding, exclusive of any cut slopes.

Based on the analyses presented in this report, the refuse slopes (3H:1V) will be stable and likely sustain minimal deformation during the design earthquake. Seismic deformation of the cover may be on the order of 12 inches. This deformation is similar to what would be expected on the cover due to normal settlement of the landfill, is generally within the range of reported allowable strains for synthetic liners, and is not considered to be excessive.

8.9 DESIGN SPECIFICATIONS AND CONSTRUCTION QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

A conceptual construction quality assurance plan is presented in Appendix H. Construction of any major design element is many years into the future since landfilling over the existing unlined area will continue for 15 to 20 years. Because changes in regulations and technology are likely to occur prior to construction of the expansion area liners, a detailed QA/QC and the design specifications are not included in this document (as agreed in the February 11, 1997 meeting with ADEQ). These documents will be submitted to ADEQ for review and approval prior to construction.

8.10 LANDSCAPE PLAN

The City of Flagstaff has worked with the USFS in the development of a landscape plan for CLL. Vegetation which occurs surrounding the landfill consists of open ponderosa and pine forest with a sparse cover of rabbit-brush and grasses and herbs.

The USFS has recommended that the City of Flagstaff develop a final cover landscape plan that would simulate, as much as possible, existing natural surface conditions (USFS, 1994). Due to the predominance of cinder deposits in the area, the USFS suggested that black cinders be used as the final cover to match the area surrounding the landfill and that reseeded or revegetation of the landfill cover may not be appropriate unless it is necessary for erosion control purposes. Therefore, minimum of 6 inches of cinders will be deposited over the landfill area. Seeding and planting will not be necessary, as a vegetative cover will not be utilized. Native species may recolonize the area over the long term. It should be noted that hydroseeding with a native seed mix may be used for erosion control purposes on interim slopes that may remain exposed for more than 1 year.

During excavation of the proposed lateral expansion, overlain cinders will be stockpiled for future final cover material. Additional cinders for use as final cover may be obtained from several existing cinder borrow sites in the vicinity.

Significant erosion of the cinders is not expected to occur. However, the cinder cover will routinely be visually inspected for gully erosion, especially following a major storm event.

8.11 CONSTRUCTION REPORT

The City of Flagstaff will submit a construction report detailing conformance and non-conformance to approved engineering plans and QA/QC testing requirements to ADEQ within 45 days after the construction for a lined cell is completed.

8.12 ALTERNATIVE LINER DEMONSTRATION

40 CFR §258.40(b) and Arizona Regulatory Statute (ARS) §49-761.B requires new MWSLFs be lined with a prescribed composite liner or a liner system approved by the Director of an approved State. The prescribed liner must consist of at least a two-foot thick compacted soil

with a hydraulic conductivity no greater than 1×10^{-7} cm/s overlain by a 30-mil flexible membrane liner (at least 60-mil if high density polyethylene is used).

As indicated in Section 8.4, an alternative liner is proposed for the lateral expansion areas. The alternative would incorporate a geosynthetic clay liner (GCL) in lieu of the 2-foot compacted soil layer. This alternative liner system is currently a more cost-effective system due to the unavailability of clay in the area.

Infiltration rates through both the prescriptive and the alternative liners were modeled using the computer program HELP (version 3.05) developed by the EPA. The model incorporated site specific temperature and precipitation data. Low percolation rates, on the order of 5×10^{-4} to 1×10^{-2} inches per year, were calculated for both liner systems. The results of the HELP modeling indicate that percolation through the prescribed liner system would be greater than that through the alternative GCL liner system. These results indicate that the alternative liner would provide equal or better aquifer protection than the prescribed liner. A detailed discussion of the HELP model, parameters selected, and the calculated results is presented in Section 9.6.1.

8.13 ALTERNATIVE FINAL COVER SYSTEM DEMONSTRATION

40 CFR §258.60 and ARS §49.761.B require final cover systems have a permeability no greater than or equal to that of the base liner system, or no greater than 1×10^{-5} cm/s, whichever is less. The Director of an approved State may approve an alternative final cover design that achieves a reduction of infiltration comparable to the prescribed cover systems.

Unless the costs of geosynthetic liners drop considerably the City would propose a pilot 3½-foot thick monolithic cap consisting of compacted local soils for Area D (see Drawing 5). The HELP program was used to model this configuration, as discussed in Section 9.6.1. The results of the HELP model suggest that during the post-closure period, 2.4 inches (per square foot area) of leachate would be collected in the LCRS beneath the refuse annually. Practice has shown that the HELP model over-estimates quantities of leachate generated by waste cells, particularly in climate with low annual precipitation rates.

It is envisioned that as part of this pilot monolithic cap project, leachate collected by the LCRS for Area D will be monitored and reported on a monthly basis following the closure of Area D. If no leachate is collected by the LCRS system for a period of at least three years (including at least one year with precipitation rates higher than normal), the City of Flagstaff will request that the ADEQ approve the monolithic cover as an alternative final cover system for Areas D and E. If leachate continues to be generated in Area D after the trial period for the monolithic cap, the City will replace the cap on Area D with the final cover specified in Section 8.6 and to use this final cover for Area E.