Merlin Landfill Forest Restoration
Test Plot Demonstration
A Summary of Findings

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Ponderosa pine – long tube container – Nov 2004

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The following report documents the revegetation work conducted over the past six months to test various methods of restoring trees to portions of the Merlin Landfill. The Forest Service entered into an agreement with the City of Grants Pass in April 2004 to advise on reforestation techniques, supply plants, deer protect, monitor seedling survival and propose direction and strategies for restoring the remainder of the borrow area with native plants. David Steinfeld prepared this report in collaboration with Greg Carey.

Summary

Findings from the Spring 2004 trial indicate that establishing seedlings at the Merlin Landfill borrow site is possible given certain reforestation/restoration methods are used. These include using species and seed sources adapted to low elevation, SW Oregon sites; planting large container seedlings; amending the soil with composted organic matter; applying a surface mulch around seedlings; and keeping competing vegetation away from seedlings until they are well established. This report summarizes the work performed in a spring and fall site preparation/planting and recommends strategies for future restoration work.

Background

On March 31 David Steinfeld (Forest Service), Mark Amrhein (Amrhein Associates, Inc.) and Bill Peterson (City of Grants Pass) met at the upper soil borrow area at the Merlin Landfill to discuss the potential for reforesting the site with native tree species. At that time it was acknowledged that even with the best restoration techniques this would be a very difficult task because of the shallow decomposed granite soils and the hot, dry summer climate. After some discussion we decided to establish a trial on the site to test several of the most promising restoration techniques. Even though we were at the very end of the “planting window” for low elevation, interior valley sites, we decided that by installing a trial at this time we could still learn enough to help us understand the potential of the site and direct future reforestation work. Because this site has unique challenges, we decided to approach this project using a variety of techniques and technologies that have the best chances for success. Integral with this approach is monitoring the successes and failure and adjusting future work accordingly.

Quite surprisingly the trial came together within two weeks following our initial meeting. In that time period approximately 1.25 acres were amended with JO-GRO compost and deep ripped; 257 seedlings were planted, deer protected and mulched. By June a drip system had been constructed and seedlings were periodically being irrigated. Instrumental to this work being quickly accomplished, was the coordination between Mark Amrhein, JO-GRO, and Copeland Sand and Gravel to purchase, deliver and incorporate mulch and the work by Greg Carey in overseeing the placement of mulch, planting seedlings, deer protection and irrigation. The methods for this portion of the project are outlined under the following Methods-Spring 2004 Plant.

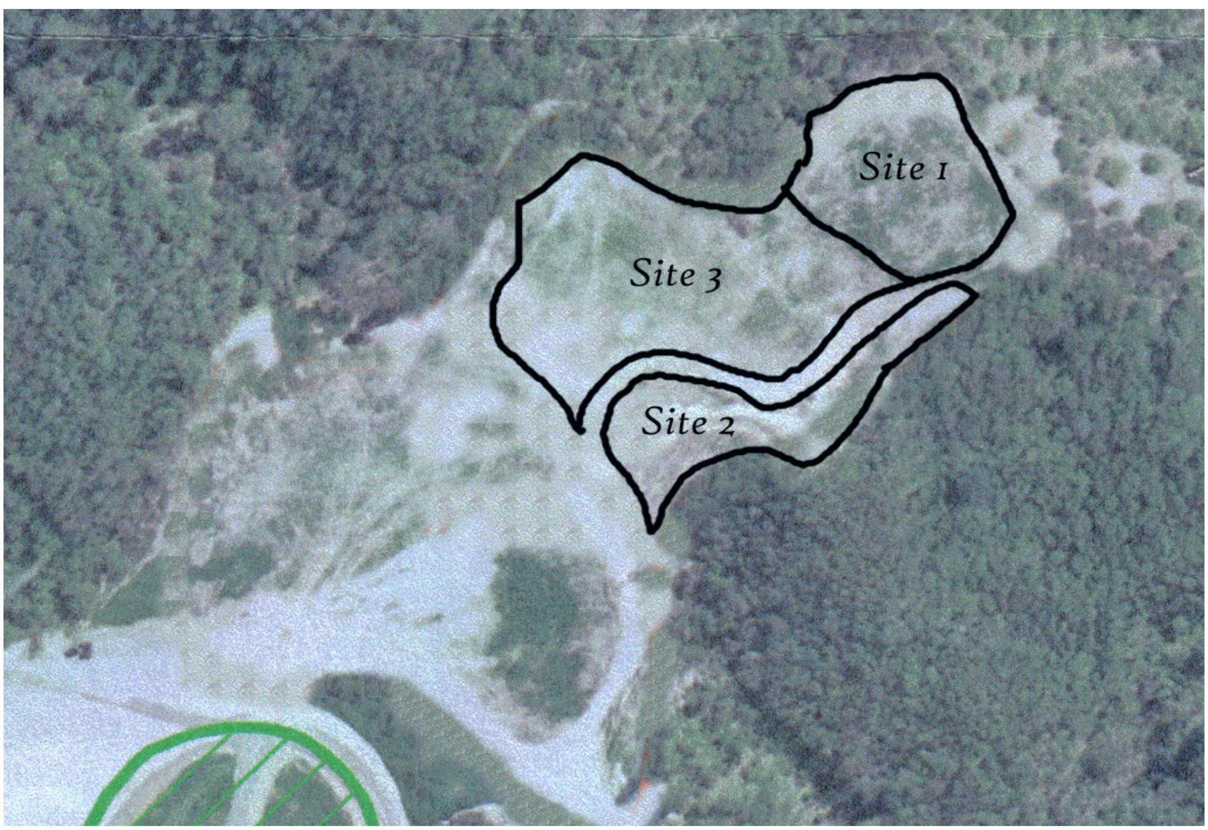
Seedlings were monitored through the summer and early fall 2004 and the results are presented under Findings – Spring 2004 Plant. From these findings, methods were refined and the soils of several adjacent areas were amended with JO-GRO compost and fall-planted with large stock. These procedures are described in Methods-Fall 2004. In Next Steps, the report discusses alternative methods to establishing seedlings on future portions of the Merlin Landfill and concludes with site-specific recommendations for areas in Strategies for Reforesting the Remainder of Merlin Landfill.

Site Description

Prior to excavation, the borrow site was composed of a moderately deep gravelly sandy loam soil (Siskiyou Soil Series). At a soil depth of 20 to 40 inches, a highly weathered, granodiorite bedrock occurred. During capping of the landfill, soils and weathered bedrock were excavated from the borrow area; resulting in a surface many feet lower than the original land surface. Exposed weathered bedrock was covered with 3 to 4 inches of silt collected from the sediment pond. Over time weedy plant species, including star thistle, wild mustard, medusahead and ripgut brome invaded the site. The resulting soil is now a shallow fine textured layer of soil over weathered bedrock that supports weedy grasses and forbs but no trees or shrubs.

Deep active gullies have formed in steeper portions of the landfill in response to the shallow, compacted soils and smooth soil surface (lacking obstacles and micro-relief to slow down overland flow).

Figure 1.



Two sites were selected in the borrow area as shown in Figure 1. Site 1 is approximately one acre located at the top of the borrow area on a gently sloping, north facing slope. Site 2 a steep (20 to 35% slope gradient), north to northeast-facing slope and covering approximately 0.25 acres. Long slope lengths (extending up into Site 1) and a road access that intercepted and concentrated the runoff are responsible for several gullies in Site 2. Site 3 was planted in Fall 2004 and it includes approximately one acre.

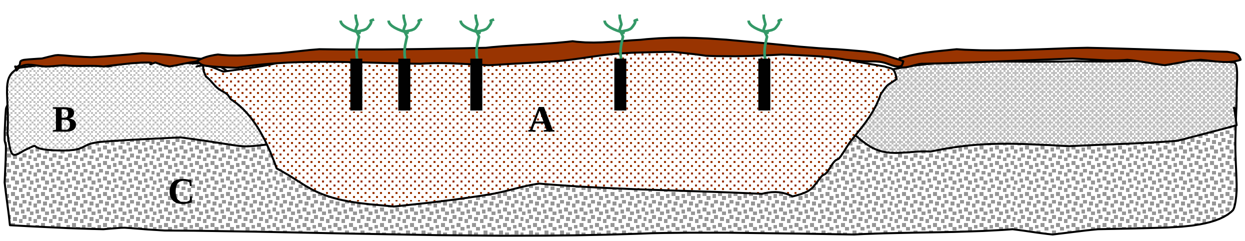
Methods –Spring 2004 Plant

The strategy behind the reforestation techniques applied to the borrow area was threefold:

- Incorporate semi-decomposed organic matter into the soil to improve soil properties
- Plant large, native tree seedlings from locally collected seed sources to improve seedling survival and growth
- Add surface mulch to reduce soil moisture loss through evaporation

The first phase of the strategy involved delivering 1350 cubic yards of unscreened JO-GRO compost. The material was delivered in a belly dump truck and laid out in piles on each site. Using a D8 tractor, the material was spread across the site to a target depth of 2 to 6 inches however, since the D8 could not spread to a consistently even depth, there were many areas where the depth was greater than 6 inches. After the material was placed, the weathered bedrock was ripped to a 3-foot depth by pulling a one-tooth shank behind a D8 tractor. After the first pass, the site was cross-ripped at 90 degrees to further fracture the bedrock. In addition, in site 2, the gullies were filled with soil and covered with mulch.

Figure 2. Diagrammatic cross section of a planting island. A) planting island - compost mixed to 3' soil depth and covered with 3 to 4" of mulch; B) granite soil covered with 2 to 6" of mulch and ripped to a depth of 2 to 3 feet; and C) decomposed granitic bedrock.



The areas to be planted, referred to as "planting islands" (Figure 2), were established by flagging out the locations on the ground. Planting islands were located approximately 30 to 40 feet from each other and encompassed a 200 to 300 square foot area. Approximately 35 islands were created. Using the bucket of a backhoe the soils within each planting island were scooped and mixed to a depth of between 2 and 3 feet to thoroughly mix the mulch into the soil. This was a very quick operation taking approximately 5 minutes per planting island. Assuming that the organic material was mixed evenly to at least 3 feet, a high rate of 6 inches of organic material applied to the surface and mixed into the soil would equate to around 15% organic material by soil volume. Since bedrock is highly weathered, mechanical tillage using the bucket of the backhoe produces a soil texture similar to the original surface layers – a gravelly sandy loam. The result are planting islands with a high organic, sandy loam soil.

JO-GRO compost, according to a Wallace Laboratories analysis (report attached), appears to be a suitable soil amendment at the rate that the material was applied to the soil. This material is a partially decomposed mix of assorted residential yard material and swage sludge composed for 120 days. It is high in the major nutrients and because of the relatively low C:N ratio (17:1 for the unscreened material), tie-up of nitrogen through the decomposition of organic matter should not be a significant issue. The Wallace report indicates that the unscreened material has a pH of 7.54 and a salinity of 6.28 millimho/cm, both values on the high side. Ponderosa pine can tolerate alkaline conditions but salinity at these levels can reduce tree growth and even survival. Thoroughly mixing the organic matter with the native granitic soil will buffer these effects.

The unscreened JO-GRO has a high content of coarse wood. 16% of the material is greater than a 0.5 inches and is composed primarily of tree branches. While large material is usually considered undesirable for most crops, we believe that this material will stay in the soil system for decades, acting as "wedges" to keep the granitic soils open, allowing roots to penetrate into deeper portions of the soil profile. The larger organic material has undergone some decomposition and will become reservoirs for longer-term soil water storage. Several soil samples taken from where seedlings were planted show that there is 2 to 3 times greater water storage in the mixed composed/soil than in the native soil. The increase in soil moisture should be directly related to the ultimate establishment and growth of conifers on the site. There is a downside of too much organic matter however - soils with extremely high organic matter, especially if compacted, can have a reduced permeability, creating saturated soil conditions which are detrimental to most conifers. These conditions were seen in areas where seedling mortality occurred.

Ponderosa pine seedlings were planted during the second week of April. These seedlings were grown from locally adapted seed sources collected from low elevation Southwestern Oregon sites (Figure 3). Weather conditions on the first week of planting were hot (mid 80^{o}F's) but cooled during the following week due to a cloud cover and intermittent rain.

Three different seedling stocktypes were planted on these sites:

- 2-0 bareroot
- One-gallon tall pot
- 18" long tube

The 2-0 bareroot is a smaller seedling than either the one-gallon tall pot or the 18" long tube and is delivered without soil or media around the roots. The one-gallon and 18" long tube seedlings, on the other hand, are much larger and their root systems are grown in rooting media (or plug) which remains around the root system during planting. The advantage of bareroot seedlings is it's cost and availability – generally bareroot seedlings are a tenth or less the cost of a one gallon tall pot or long tube seedling and typically available on short notice. Long tubes and one-gallon containers are often difficult to obtain (they must be ordered a year in advance) so it was fortunate last spring that Stone Nursery had a surplus of these stocktypes suitable for this area. Nevertheless there were not enough large container stock (one-gallon and tall pots) for the entire project; so the bareroot seedlings were supplemented with the larger stock (Figure 3). Vexar tubes were placed over all seedlings to protect them from potential deer browse. Between 6 to 15 seedlings were planted on each island. Site 1 was planted with 170 seedlings and Site 2 with 80 seedlings.

Figure 3. Seedlots and stocktypes used in the spring planting.

Seed Source ID	Species	Stocktype	# Seedlings
PIPO-11-502-20-64 NV	Ponderosa pine	2-0 Bareroot	145
PIPO-11-502-20-64NV	Ponderosa pine	1-Gallon	82
122-512-1.5-2.2-CJ1	Ponderosa pine	Long Tube	30

After the islands were planted, unscreened JO-GRO compost was used as a surface mulch to reduce surface evaporation and weed invasion. Each island received approximately 3 yards of compost which was spread to a depth of 3 to 4 inches. Where feasible, the backhoe operator roughly spread the piles over the planting islands, avoiding the seedlings. The islands were then hand raked to obtain an even depth. Mulch was not placed in contact with the stem of the seedlings to avoid possible heat build up and weakening due to high salinity levels.

Soil moisture during planting was generally high. The one-gallon and tall pot containers were irrigated before planting assuring that there would be moisture around the developing new roots during seedling establishment in the spring. In contrast bareroot seedlings do not have high water-holding media around the roots that help maintain high moisture around the root system during the critical period of seedling establishment.

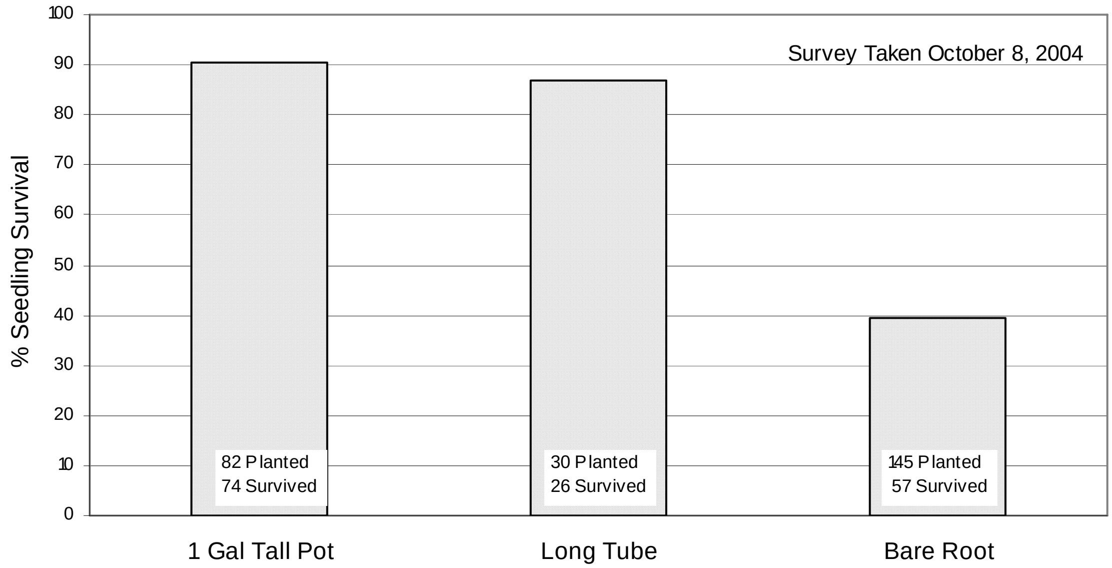
When we made the decision to plant these sites late in the "planting window" our concern was that the seedlings would not have enough time to develop roots before the weather turned hot and dry. For this reason a gravity-feed drip irrigation system was installed. It included two 2500-gallon storage tanks placed at the highest elevation on the site. These connected to a 2-inch mainline with manual on/off valves and a filtration system suited to the impurity of the water. The system was reduced to 1 inch laterals followed by ½ inch feeder lines extending to 4 gallons per minute emitters placed one at each seedling. A manual valve separated the Site 2 irrigation system and it was kept partially closed to reduce the lower slope water pressure and maintain similar emitter flows. Seedlings were irrigated on five occasions during the summer – June 8, June 21, July 15, July 21 and August 18. All irrigations used approximately 1200 gallons except for the July 21 irrigation, which used 2000 gallons. Assuming that all irrigation emitters supplied equal amounts of water, each seedling would have received nearly 8 gallons of water per irrigation or approximately 40 gallons over the course of the summer.

Weeding establishment was minimal during seedling establishment. Nevertheless, star thistle was hand pulled from the two planting sites in the summer and jimson weed, pigweed (or possibly amaranth), wild mustard and other garden weeds were removed in September. This work was important for reducing seedling competition and eliminating weed seed sources. Vexar tubing was removed from the seedlings because of the lack of apparent deer browse due to the fence that was installed around the site during the summer. The tubes could have remained in place but due to the size of some seedlings, it is possible that the netting could restrict future seedling growth.

Findings – Spring 2004 Plant

Seedling survival was conducted on five different occasions over the summer and fall. A 100 percent survey of all planted seedlings taken on October 8, 2004 showed that of the 257 trees planted, 157 survived for a total seedling survival rate of 61%. By planting area, of the 212 seedlings planted on Site 1, 136 survived and 21 survived out of the 45 seedlings planted on Site 2. Initial stocking levels for both areas are approximately 135 seedlings per acre. Seedling mortality occurred primarily in the bareroot stocktype (Figure 4) with more than 60% of the seedlings dying by the end of the summer. The large container-grown seedlings (1-gallon tall pots and long tubes) on the other hand had very good survival, displaying less than 15% mortality.

Figure 4. Seedling survival by stocktype



Seedling mortality was caused by a combination of several factors. Viability of bareroot seedlings will decrease over time in cold storage and the seedlings used on this project had been stored for almost four months. Furthermore, since bareroot seedlings come directly out of cold storage and are planted, it takes several weeks for the physiological functions of the seedlings to be fully operational, whereas the large container-grown seedlings have been grown outside and are fully functioning at the time of planting. The several week lag before bareroot seedlings become fully functioning and in tune with the environment can be very stressful to seedlings, especially if the weather turns hot and dry. Had bareroot seedlings been planted several months earlier, the mortality rates of the bareroot seedlings would have been much less because of the milder climate during seedling establishment.

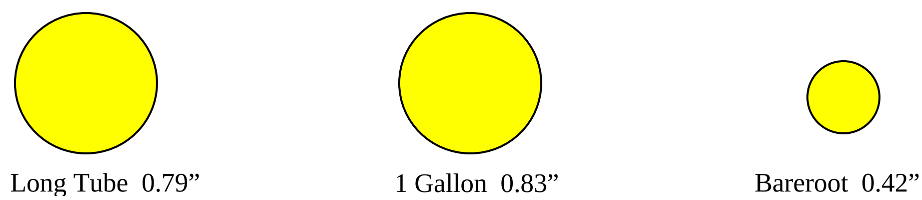
Another cause of mortality in both bareroot and large container-grown seedlings was the high soil moisture associated with the frequent irrigations in areas where organic matter levels were very high (greater than 50 percent by soil volume). In these areas saturated soil conditions around the root system created unfavorable growing conditions, resulting in root disease and in some cases, subsequently seedling mortality. Of the few large container-grown seedlings that died, inspection of the soil directly surrounding the roots of the plug showed that the soil was composed primarily of JO-GRO compost and very high moisture contents (nearly saturated). The roots of these dead seedlings had rotten. The Wallace report warns of the potential problems with high organic matter – "excessive organic matter is undesirable since it can cause a loss of soil aeration if the soil is compacted or is placed in deep profiles". Compounding this, the high salinity levels of the unmixed JO-GRO places the developing seedling under further stress.

A secondary cause of mortality in the large container-grown seedlings was the damage caused by the flatheaded borer larvae (*Chrysobothris sp*). This insect chews through the stem of the seedling, but infests only conifers that are already weakened, dying or dead. Several seedlings in Site 2 were found with flatheaded borer damage but these seedlings would likely have died due to root disease.

After several minor rainstorm events, surface runoff from sites 1 and 2 appear to be minor. There is still concentrated runoff on the access road but no apparent water concentration where the gullies had existed. The addition of the organic matter as a mulch and soil amendment, in addition to the very rough micro-relief of the surface has greatly increased surface infiltration and reduced or eliminated runoff in the treated areas. Runoff and erosion is still expected to occur on any compacted soils, such as road surfaces.

Stem diameters measured directly below the cotyledon scar[1] are beefy for newly planted stock, approaching an inch in diameter for the large container-grown seedlings but less than half the diameter for the bareroot stock (Figure 5). Stem diameter has been shown to be the one seedling attribute that correlates greatest to seedling survival and growth. The large stem diameter on many of the planted seedlings indicates that these seedlings are very healthy and well established.

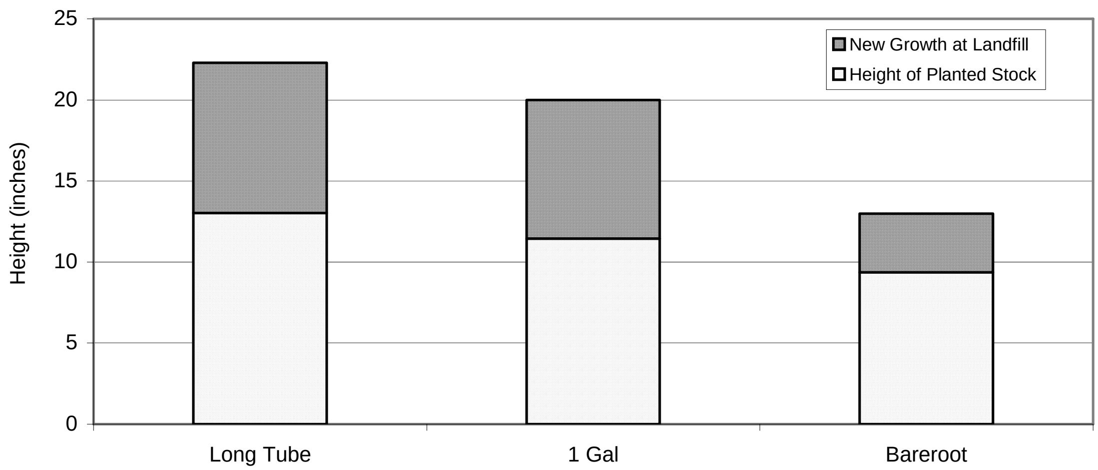
Figure 5. Average stem diameter (November 5, 2004)



Growth rates for seedling tops were very high for the large container-grown seedlings, approaching a total average height of close to 2 feet, whereas bareroot seedlings averaged just over a foot in height (Figure 6 and cover page picture). More impressively, the large container-grown stocktypes grew more than 40% of their total height after they were planted last spring. The bareroot stock, on the other hand, averaged 25%. It is not unexpected to see the large first year growth differences between bareroot and large container-grown stocktypes, primarily because most bareroot seedlings often experiences some level of "transplant shock" immediately after outplanting. However once established in the second or third years after outplanting, bareroot seedlings often grow well. It is unlikely however, that the bareroot seedlings catch up to the growth rates of the large container-grown seedlings.

[1] The cotyledon scar is usually found on the seedling stem near the ground line and often considered the point where root and shoot meet.

Figure 6. Height and leader growth of planted stock (November 5, 2004)



Partial excavation of the roots system from several healthy large container-grown seedlings showed that the root system had grown out from the container plug and into the surrounding soil. In several instances fine feeder roots were observed to be actively penetrating the incorporated organic material, an indication that the organic material is a compatible and desirable rooting medium for conifer seedlings. A lateral root system of one seedling was excavated and found to extend over two feet away from the seedling, suggesting that this seedling as well as others were well established.

Methods – Fall 2004 Plant

What we learned in the spring 2004 planting trial, we applied to a fall planting trial. Fall planting occurred in areas with high mortality on Sites 1 and 2. Site preparation occurred in a new area - Site 3 - prior to planting. The following are the major differences between the spring and fall planting trials:

- Fall and late winter planting. If the conditions are right, seedlings planted in the fall or late winter should have greater success in establishment than spring planted seedlings. In order for a seedling to become established after planting it must have several months where the climate is warm enough for adequate root growth (generally above 42^{o}F), when adequate soil moisture is present and there is moderate “above ground” climate conditions (neither extreme heat or cold). At the Merlin Landfill site, these conditions are present in the fall and late winter. Early fall planted seedlings have an added advantage because they have two root growth seasons (fall and the following spring). The longer seedlings have to develop roots into the native soil before the summer draught, the greater the chances for survival and optimum growth. For the Fall 2004 Plant we intended to have the site prepared for planting by early October but due to scheduling problems, the site was not planted until mid-November. The drawback to the late planting is that new roots growth is minimal before winter hits. This is probably not critical since the root system in the container is well established and should be able to survive a rare deep freeze (once in 10 year event).

- New mulch. In October 2004, 860 yards of unscreened JO-GRO was applied to Site 3 prior to planting in a manner similar to the spring site preparation. The incorporation of JO-GRO in the soil is the most expensive part of this restoration project yet we feel that it is essential to the long-term productivity of the site. Not only will it significantly increase soil moisture and rooting depth but it will also increase the vitality of the biological system by supplying nutrients and carbon to fuel biological activity. Our experience with compacted granitic soils is that they can be ripped or subsoiled to increase soil porosity but if there is no addition of organic matter, the soils will settle back to their original bulk densities within a few years. Organic matter not only keeps the soil open, allowing root penetration, but will decompose over time to a friable soil, rich in humus.

- Large container-grown stock and new species. Bareroot seedlings are not commonly available in the fall for outplanting and when they are available, they often do not perform well as compared to container stock. The findings from the Spring Plant also support the use of large container-grown seedlings for greatest survival and growth (Figure 4). Several new species were planted during the fall to increase the diversity of species on the project (Figure 7). Areas where seedlings had died last summer were replanted with seedlings during the Fall-plant.

- Seed placement and shelters. White oak and madrone seeds were sown in two different types of tree shelters as a very inexpensive way to increase the diversity of plant species in the project area. Seeds were collected from adjacent lands ensuring optimum genetic site adaptability. Madrone seedlings were interplanted next to the seeds to compare seedling establishment and growth by the two methods. Tree shelters (Figure 8) cut in half and film sheets were placed around each seed to protect them from animal damage and create an optimum microclimate for seedling establishment. Areas where seedlings had died last summer were replanted with seed during the Fall-plant.

Figure 7. Seedlots and stocktypes for fall planting.

Site #1 Replant – 50 Seedlings, 137 Seeds

Seed Source Collection ID	Species	Stocktype	# Seedlings or seeds
PIPO-15-15023100-2435-91 SIA	Ponderosa pine	1-Gallon	24
ARME-15-492-02-100-20SAIT-98 NC	Pacific madrone	18" Long Tube	15
AMAL-15-492-02-100-2500--99	Serviceberry	18" Long Tube	11
Collected on adjacent lands	California Black oak	Seed	12
Collected on adjacent lands	Oregon White oak	Seed	75
Collected on adjacent lands	Madrone	Seed	50

Site #2 Replant – 76 Seedlings, 110 Seeds

Seed Source Collection ID	Species	Stocktype	# Seedlings or seeds
PIPO-15-15023100-2435-91 SIA	Ponderosa pine	1-Gallon	23
PSME-15-492-02001-25-78 SIA	Douglas-fir	1-Gallon	16
LIDE-15-492-00GL-20-91 SIA	Incense cedar	1-Gallon	26
AMAL-15-492-02-100-2500--99	Serviceberry	18" Long Tube	6
ARME-15-492-02-100-20SAIT-98 NC	Pacific madrone	18" Long Tube	5
Collected on adjacent lands	California Black oak	Seed	7
Collected on adjacent lands	White oak	Seed	26
Collected on adjacent lands	Madrone	Seed	77

Site #3 First Plant – 175 Seedlings, 242 Seeds

Seed Source Collection ID	Species	Stocktype	# Seedlings or seeds
PIPO-15-15023100-2435-91 SIA	Ponderosa pine	1-Gallon	83
PSME-15-492-02001-25-78 SIA	Douglas-fir	1-Gallon	27
LIDE-15-492-00GL-20-91 SIA	Incense cedar	1-Gallon	29
AMAL-15-492-02-100-2500--99	Serviceberry	18" Long Tube	18
ARME-15-492-02-100-20SAIT-98 NC	Pacific madrone	18" Long Tube	18
Collected on adjacent lands	California Black oak	Seed	17
Collected on adjacent lands	White oak	Seed	100
Collected on adjacent lands	Madrone	Seed	125

- Planting care. There appears to be some potential risk in having too much compost in contact with the root system (see discussion above on salinity and high moisture of JO-GRO). To reduce this risk, the compost was kept from direct contact with the seedling plug during planting. In soils where compost material was high, an 8-inch diameter hole was dug and seedling planted with a 2-inch buffer of decomposed granite placed around the root plug. This should reduce seedling stresses associated with high salinity, saturated soils and poor aeration during the first growing season.

- Spiraling roots. Another planting problem was the spiraling of the lower roots at the bottom of the one-gallon containers. If these roots are not cut before planting, the seedling does not develop roots from the bottom of the container. We observed this on several excavated seedlings from the Spring Planted trial. The spiraling roots of the bottom of all one-gallon seedlings will be severed in the Fall plant with a sharp blade. The long-tube seedlings do not have this problem due to the open-bottom design of the container planted seedlings

- Seedling Protection. Vexar tubing for deer protection was removed from the Spring-planted seedlings and not installed on the Fall-planted seedlings except for the madrone and serviceberry because of the lack of deer damage observed last summer. The lack of damage was probably due to the deterrence of the fence coupled with the fact that ponderosa pine is not a preferred browse species for deer. Madrone and serviceberry are preferred deer forage and they are being protected with tree shelters (Figure 8). These structures act like mini-greenhouses, allowing solar radiation in, protecting the seedling from wind desiccation and creating a high moisture environment. Under certain situations, moisture will condense on the walls of the tree shelter at night and drip into the soil, adding soil moisture.

- No irrigation. Soil moisture was very high in holes that were dug in late August. This was observed outside of the influence area of the drip irrigation emitters, indicating that the surface mulch coupled with the lack of competing vegetation on the site had maintained high soil moisture throughout the summer. In some cases, the high rates of irrigation actually harmed the seedlings and were probably responsible for some of the seedling mortality (see discussion above). For this reason and because seedlings are being planted within the "planting window" for the site, we felt that it was unnecessary to drip irrigate any newly planted seedlings. Seedling monitoring (using plant moisture stress equipment) next summer will indicate if seedlings need to be irrigated. If this is the case, we could reestablish the irrigation system.

- Introduce native grass and forb species. One of the functions of surface mulches is to reduce weed establishment, however because the unscreened JO-GRO co-compost has some fines (16% of the material is less than 2mm and 48% is less than 6mm) it has a greater potential for weed invasion than mulches with less fines. The fine fraction will be a good seedbed for some germinating seeds that are either present in the organic material or will blow onto the site from the surrounding adjacent area over time. This fall we observed many mulched areas that were beginning to show presence of high amounts of germinating weed seeds. To reduce the presence of weed species, a mix of native forbs and grasses[2] were sown where bare soils or fine materials were present. The seed mix included California fescue (FECA), Hardford's melica (MEHA), Oregon sunshine (ERLA), buckwheat (ERNU), yarrow (ACMI) and blue wild rye (ELGL). Seed was not sown near planted seedlings to reduce the potential for seedling competition.

Figure 8. Tree shelters placed around madrone seedlings to protect from deer browse, increase air temperatures, and reduce moisture loss.

[2] Seed grown and harvested at Stone Nursery from low elevation, SW Oregon seed collections

Next Steps

Findings from the Spring 2004 trial indicate that establishing seedlings at the Merlin Landfill borrow site is possible given certain reforestation methods are used. Nevertheless, caution should be taken in drawing too many conclusions from first year successes especially on a harsh site like the Merlin Landfill, where practices using high rates organic material are being tested. Several unknowns still wait us such as – what are the long-term effects of high soil organic material on seedling nutrient availability? Will the high rates in some way limit seedling growth? Will the shallow overall soil depth limit future sapling and tree growth? Will weeds brought in with the organic matter become a severe problem to seedling growth? Obviously we will not be able to answer these and other questions for some time. The lack of answers however, should not restrict future work. Based on this year's findings we know that if we use similar reforestation and soil improvement methods we should have good seedling establishment on similar sites.

Figure 6 gives a good indication of the type of growth rates that could be expected in the short term on this site. Assuming no unforeseen problems arise, it would be realistic to expect a minimum growth rate of one foot a year to continue for the foreseeable future. This would mean that in a decade, seedlings would be over 10 feet and show some visual presence from a distance and within two decades, the site would be dominated by 20-foot tall saplings.

While the spring planting trial appears to be very successful, there are always doubts and second-guessing – "did we overdo it?" or "could we have done it cheaper and still succeeded?" The next steps in this effort are to try to reduce the costs while still achieving good survival and long-term growth. Future work could consider the following measures to reduce costs.

- <u>Less JO-GRO.</u> The amount of JO-GRO compost applied in the future should be much less. Figure 9 shows the rates of JO-GRO that was applied to each site and the expected nitrogen release over time. Claassen and Hogan (1998), in a very thorough review of the research of compost additions to granitic soils determined that an annual release rate of 55 pounds of N from municipal composts would be sufficient to maintain long-term establishment of plants. Applying their assumptions to this project, JO-GRO was applied at rates three times the needed rates for sustained nitrogen release. Future JO-GRO rates could be as much as a third the rates, or 4400 pounds per acre. If JO-GRO were limited to just the planting pockets there would be a future reduction in the amount of material needed per acre.
- <u>Smaller containers.</u> The large containers planted in the spring and fall trials were used primarily because they were the only large stocktype available. Smaller container stocktypes (greater than 20 cubic inch in plug volume) should survival well, especially if planted in late winter/early or in the early fall (only if soil moisture is high). Several different containers could be used – D40's, Styro20's, STP (half gallon container) but orders need to be placed at a nursery in September to October to have seedlings available in one to two years.
- <u>Less expensive mulch</u>. There are other sources of material that could be used as a surface mulch. One product that was used recently on a FHWA project near Chiloquin Oregon is a sawdust waste-product from the manufacturing of medite. This material is often available at no cost except for the delivery to the site from Medford Oregon.

- Different tillage method. Instead of using either a tractor or excavator to mix JO-GRO in the soil, other machinery could be considered. On flatter slopes, the "spadder" is a possibility. This machine has a gang of shovels that rotate and thoroughly mix the soils to 20 inches. The Stone Nursery owns this machinery and might be able to use it on the site.
- Soil tests, foliar tests, fertilizers and gypsum. Seedlings will reveal if there are nutrient deficiencies. The most obvious indication of nutrient deficiency is the color and vigor of the seedling. A more reliable method is to perform a foliar nutrient analysis conducted by a reputable lab. At the present time, seedlings appear to have adequate nutrition. Future monitoring will indicate if fertilizers or gypsum should be applied around the seedlings. Following Wallace Lab's recommendation, gypsum could be added with the mulch when applied to the next areas to be planted.
- Monitoring. It is imperative that each planting area be monitoring for survival and growth for at least three years. Minimum collection data should be seedling survival and growth. Other beneficial measurements would include soil moisture monitoring through the summer, pre-dawn plant moisture stress (PMS), foliar analysis and soil tests.

Figure 9. Estimated available pounds of nitrogen (N) per acre for different sites (after Claassen and Hogan 1998).

sites	cubic yards applied	acres applied over	# N/cubic yards of JO-GROW (from Wallace Report)	Total pounds N per acre	% of total N released per year	available N	target pound per acre available N
1&2	1350	1.25	11	11880	1.5	178.2	55
3	860	1	11	9460	1.5	141.9	55
Future Sites	400	1	11	4400	1.5	66	55

Strategies - Reforesting the Remainder of Merlin Landfill Borrow Area

See Figure 10 for location of the following sites.

Site 4. This site is directly below Sites 2 and 3. It has a north facing aspect and relatively gentle slopes. Of the remaining sites to reforest, this site appears to be the most visible from the surrounding area and therefore have the highest priority for reestablishing trees. As discussed above, amending the soils with JO-GROW, deep tilling and planting is recommended. The area where larger branches and woody material was buried will present problems in tillage and in these area, simply planting seedlings would be the best measure. Use ponderosa pine with minor amounts of incense cedar, madrone and Douglas-fir.

Site 5. This is a steep site between two roads and like Site 4 is visible from the surrounding valley. The soils are very high in a fine organic matter (leaf compost), which in some areas prevents the soils from absorbing water (hydrophobic soils). The site needs no additional organic matter or deep tillage. The planting spots could benefit from being mixed either with an excavator or by hand. Site should be planted with large container stock in the fall or late winter with small basins built around each seedling to help pond the water in case the soils be hydrophobic. Grass will reestablish quickly so it is very important to put down weed barrier cloth at the same time the site is planted. Use ponderosa pine with minor amounts of incense cedar, madrone and Douglas-fir.

Site 6. This site is less visible from the valley because it is flat and portions (northeast section) are blocked by the landfill. This is a highly compacted bench, which will need deep tillage and additions of organic matter similar to Site 4. Use ponderosa pine with minor amounts of incense cedar, madrone and Douglas-fir.

Site 7. This is a west-facing slope with deep soils that have been amended with compost. It is ready to plant. There must be vegetation control around the seedlings (weed barrier clothe) and shade cards (western aspect) for several years after planting. Use primarily ponderosa pine and serviceberry, with minor amounts of incense cedar, madrone and Douglas-fir

The benches near the intermittent drainage have had sediments deposit over the past few years so the soils are deep with a high water table in the winter. Riparian species should be able to survive in this area. Plant with willows and cottonwoods and keep vegetation away from the seedlings for at least one year.

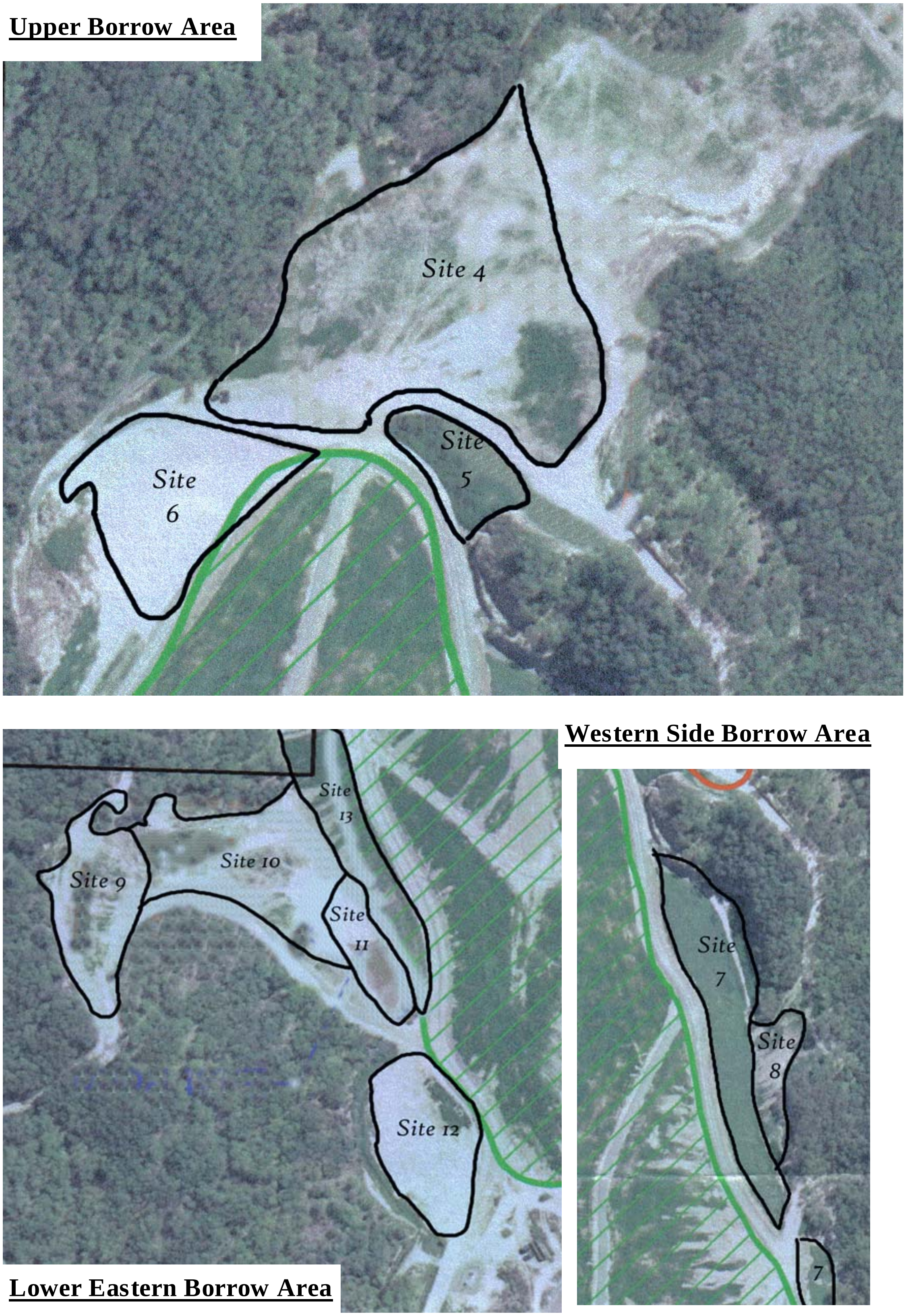
Site 8. This is small area surrounded by native forests that has been severely disturbed. Because it is relatively protected, ripping the soils to two to three foot depths and planting with high quality seedlings might be sufficient to economically reforest this site. A combination of Douglas-fir, ponderosa pine and incense cedar would be appropriate.

Site 9. This is a steep headwater slopes that drains to Site 10 and Site 11. It is composed of compacted, shallow soils that have undergone extensive rill and gully erosion over the past few years and has delivered these sediments to the East Pond. There is still relatively high surface soil erosion but it does not appear to be as severe as previous years because many of the rills and gullies have reached bedrock and soils are held together by a ground cover. Restoration work on this site would have to be carefully implemented so as not to increase soil erosion. Reclamation work must include a deep ripping (to 3 feet) and application and incorporation of JO-GROW. After the incorporation the site should be ripped on the contour again and surface left “rough”. The tops of the slopes are the most important areas to rip since they are the source of water. It does not take much slope gradient or slope distance for the overland water to create rills and gullies in this soil type. Since this is a very harsh site (west facing slopes) use ponderosa pine or shrub species.

Site 10. Similar to Site 9, this site has gentler slopes (20-25% slope gradients) and less surface erosion. This area can be treated similarly as Site 9.

Site 11. While revegetating the site around the East Pond will have some of the least visual screening benefits if implemented, it could have the greatest impact to long-term water quality and wildlife habitat improvement of all work done at the Landfill. Establishing wetland plants and riparian shrubs and trees would increase water quality and create habitat from dozens of birds and other animals (installing a 4 acre wetland at Stone Nursery brought in many species, relatively uncommon in the Rogue Valley).

Figure 10. Potential Restoration Sites.



Species such as hardstem bulrush, (Scirpus acutus), small fruit bullrush (Scirpus microcarpus) and cattail (Typha angustifolia) can grow 5 to 6 feet tall and be submerged in water for months. These species grow densely and "scrub" water of nutrients and other impurities. They would be good in areas where water levels fluctuate. Species like common sedge (Juncus effuses) grow well where soils dry out in the summer, but thrive with wet feet the rest of year. These species would grow well at the high water mark of the pond. Stone Nursery has locally collected seed of all these species and can grow them for $.18 to $.50 per plant. Willows and cottonwoods can be grown around the edges of the pond either from seedlings or by cuttings. There is a source of willow and cottonwood below the dam that could be cut in the winter and stuck or layered into the muck in and around the pond.

Site 12. This area is a bench bordered to the east by the stream originating from the East Pond. This area has some visibility but it's greatest value might be as riparian habitat. Use similar restoration practices as those proposed under Site 4. Species to use would include riparian species near the stream (willows already stabilize the banks) while using Douglas-fir, incense cedar and ponderosa pine away from the riparian area.

Site 13. These are steep slopes (35-40% gradients) composed of compacted soils with a thin layer of silt material place on the surface. It is a east to northeast facing slope. There are round river gravels mixed into some of this site. This does not appear to be a highly visible site and with the high costs of ripping and JO-GROW, this would be a low priority for revegetating. A low cost alternative could be considered because of the more protected climate (cooler aspect, less wind and moderating effects of adjacent forest). This would involve planting high quality seedlings and placing a large weed barrier cloth around each seedling. Realizing that the risk of seedling mortality is higher, expect 25 to 50% seedling mortality and increase the planting density accordingly.

Conclusions

Establishing seedlings at the Merlin Landfill borrow site is possible if certain reforestation/restoration methods are applied. These methods include using species and seed sources adapted to low elevation, SW Oregon sites; planting large container seedlings; amending the soil with composted organic matter; applying a surface mulch around seedlings; and keeping competing vegetation away from seedlings until they are well established.

During the initial meeting last April, we discussed the wisdom of starting with small projects, monitoring the successes and failures, and applying these lessons to the next area to be restored. Because the long term results of some of the techniques we have used on the Merlin Landfill are not completely known, moving slowly ahead with small projects while looking back at the results of previous work still seems like a good strategy.

By applying these restoration techniques to other sites in this area, the Merlin Landfill will begin to connect and integrate into the surrounding forested landscapes. By establishing native vegetation that is fire resilient, visually appealing, and low maintenance, the health of this forest ecosystem will be enhanced.

Literature Cited

Claassen VP, Hogan MP. 1998. Generation of water-stable soil aggregates for improved erosion control and revegetation success. California Department of Transportation and Federal Highway adminsitration Grant 53X461. 111p.

WALLACE LABORATORIES
365 Coral Circle
El Segundo, CA 90245
phone (310) 615-0116 fax (310) 640-6863

September 7, 2004

Fax 541/482-6750
Parametrix, Inc.
Mark Amrhein
804 Roca Street
Ashland, OR 97520

RE: Marlsan Landfill Final Cover

Dear Mark,

River Silt

This material is not suitable. It is gelatinous hydrated iron material. The received material had high moisture at about 10 times its dry weight. Physically, it is difficult to work when wet. The material contains high concentrations of iron, manganese, aluminum and vanadium. It is acidic with a pH of 6.64. The salinity is low at 0.22 millimho/cm. It contains moderate concentrations of arsenic, chromium and lead. The hydrate iron traps other metals. The material is a silty clay with 3.5% sand, 46.1% silt and 50.4% clay.

Decomposed Granite

The pH of the DG is near neutral at 6.96. Salinity is low at 0.30 millimho/cm. Iron and manganese are sufficient. Nitrogen, phosphorus, potassium and zinc are low.

JO-GRO Co-composts

Both the screened and unscreened products have high fertility and will supply sufficient fertility to the DG. The products have low carbon:nitrogen ratios and high ammonium ions. About two-thirds of the salinity is from ammonium ions. About one-third of the total nitrogen in the unscreened material is ammonium nitrogen and about one-fourth of the total nitrogen in the screened material is ammonium nitrogen. About half of the anion ions are chloride in both products

The pH of the unscreened material is alkaline at 7.54. Salinity is 6.28 millimho/cm. The carbon:nitrogen ratio is 16.8. Organic matter is 75.1%.

The pH of the screened material is high at 8.32. Dissolved ammonia is highly alkaline. The salinity is 4.61 millimho/cm The carbon:nitrogen ratio is 12.0. Organic matter is 64.9%.

Either of the two materials will supply adequate fertility. The screened material is preferred since it is more stable, has low organic matter, and has smaller particles which will better blend with the DG to condition the DG.

Soil Analyses Plant Analyses Water Analyses

Recommendations

Homogeneously blend 15% screened compost and 85% DG. Incorporate 3/4 pound of gypsum per cubic yard of the blend to help reduce the alkalinity and to help stabilize the organic matter.

A blend of 15% screened compost and 85% DG with gypsum will have salinity at about 1 millimho/cm. About half of the salinity will be from the gypsum. It will contain about 5% organic matter. Excessive organic matter is undesirable since it can cause a loss of soil aeration if the soil is compacted or is placed in deep profiles.

Sincerely,

Garn A. Wallace, Ph. D.
Executive Director
GAW:n

Soil Analyses Plant Analyses Water Analyses

WALLACE LABS	COMPOST REPORT	DATE:	September 3, 2004
365 Coral Circle	Location	Marlin Landfill Final Cover, Josephine County, Oregon	
El Segundo, CA 90245	Requestor	Mark Amabein, Paramatrix Inc.	
(310) 615-0116	Material	Unscreened JO-GRO co-compost	

graphic interpretation: * very low, ** low, *** moderate, **** high, ***** very high

ammonium bicarbonate/DTPA extractable - mg/kg soil Interpretation as media low medium high	elements	04-247-09 extractable (available) mg/kg	graphic	Total Content mg/kg	Percent Available nutrients	Total pounds per cubic yard	Total pounds per ton
0- 12 16 -28 32 -44	phosphorus	442.51	****	7,631.22	5.8%	3.4752	9.941
0-240 240-500 500-700	potassium	4,281.65	****	7,083.30	60.4%	3.2257	9.227
0- 12 12- 20 over 20	iron	89.03	****	4,773.93	1.9%	2.1740	6.219
0 - 2 3 - 4 over 5	manganese	70.73	****	348.13	20.3%	0.1585	0.453
0 - 4 4 - 6 over 6	zinc	75.74	****	325.20	23.3%	0.1481	0.424
0-0.5 0.6 - 1 over 1	copper	12.30	****	163.95	7.5%	0.0747	0.214
0 - 1 1 - 2 over 2	boron	1.35	***	18.54	7.3%	0.0084	0.024
ratio of calcium to magnesium	calcium	1,696.79	****	15,872.90	10.7%	7.2284	20.677
needs to be more than 2 or 3	magnesium	451.31	****	3,358.97	13.4%	1.5297	4.375
should be less than potassium	sodium	196.45	***	712.56	27.6%	0.3245	0.928
	sulfur	711.31	****	4,485.89	15.9%	2.0429	5.843
	molybdenum	0.49	****	2.43	20.0%	0.0011	0.003
The following trace	aluminum	0.99	**	6,904.71	0.0%	3.1444	8.994
elements may be toxic	arsenic	0.45	*	0.65	68.8%	0.0003	0.001
The degree of toxicity	barium	0.31	*	154.23	0.2%	0.0702	0.201
depends upon the pH of	cadmium	0.28	*	0.56	49.7%	0.0003	0.001
the soil, soil texture,	chromium	0.18	*	13.40	1.3%	0.0061	0.017
organic matter, and the	cobalt	0.20	*	3.08	6.5%	0.0014	0.004
concentrations of the	lead	13.54	***	50.20	27.0%	0.0229	0.065
individual elements as	lithium	0.75	*	11.89	6.3%	0.0054	0.015
well as to their	mercury	n d	*	0.19	0.0%	0.0001	0.000
interactions.	nickel	0.53	*	13.43	3.9%	0.0061	0.017
	selenium	n d	*	n d		0.0000	0.000
	silicon	8.37		n d		0.0000	0.000
	silver	n d	*	4.82	0.0%	0.0022	0.006
Generally,	strontium	4.62	*	161.26	2.9%	0.0734	0.210
the pH optimum depends	tin	n d	*	n d		0.0000	0.000
upon the organic	titanium	2.51		120.27		0.0548	0.157
matter and mineral content-	vanadium	2.09	***	352.30	0.6%	0.1604	0.459
under 5.2 is too acidic							
6.5 to 7 is ideal	**Saturation Extract**						
over 9 is too alkaline	pH value	7.54	****				

The ECe is a measure of the compost salinity: ideal about 1	ECe (milli-mho/cm)	6.28 *****	millieq/l	water soluble nutrients	percent of available
ideal 200 ppm	calcium	68.4	3.4	239.8	14.1%
ideal 25 ppm	magnesium	26.4	2.2	92.4	20.5%
	sodium	62.8	2.7	320.0	112.0%
ideal 25 ppm	ammonium as N	572.8	40.9	2,008.1	22.8%
ideal 150 ppm	potassium	754.8	19.3	2,646.4	61.8%
	cation sum		68.5		
problems over 150 ppm	chloride	916.9	25.8		
ideal 100 ppm	nitrate as N	120.8	8.6	423.6	
toxic over 800	sulfate as S	232.7	14.5	815.7	114.7%
ideal 40 ppm	phosphorus	69.4	4.6	243.4	55.0%
	anion sum		53.6		
toxic over 1 for many plants	boron as B	0.43 **		1.5	112.4%
increasing problems start at 4 - 6	SAR	1.6 *			

Percent passing	
1/2 inch	83.5%
1/4 inch	48.2%
2 millimeters	16.2%

est. gypsum requirement-lbs./cubic yard	0.4
relative infiltration rate	very slow
percent organic matter-dry wt. basis	75.12%
percent total nitrogen-dry wt. basis	2.42%
percent total carbon-dry wt. basis	40.55%
carbon:nitrogen ratio	16.8
lime (calcium carbonate)	no
percent water/total basis	34.9%
percent water on a dry weight basis	53.5%
half saturation percentage	175.3%
bulk density - pounds per cubic yard	699
exchangeable ammonium - mg/kg dry wt. basis	8,794

TOTAL Content in pounds	cubic yard	ton
carbon	184.64	528.17
nitrogen	11.00	31.46
P2O5	7.97	22.78
K2O	3.89	11.12
chloride	1.46	4.19
boron	0.01	0.02
sodium	0.32	0.93

As is basis:

Total Nitrogen 1.57%	
nitrate N 0.03%	Total P2O5 1.14%
ammonium N 0.57%	Total K2O 0.56%
Organic N 0.97%	

acid-soluble ash	7.6%
acid-insoluble ash	17.3%

Elements are expressed as mg/kg dry weight or mg/l for saturation extract.
pH and ECe are measured in a saturated extract. n d means not detectable.

WALLACE LABS
365 Coral Circle
El Segundo, CA 90245
(310) 615-0116

COMPOST REPORT DATE: September 3, 2004
Location: Marisan Landfill Final Cover, Josephine County, Oregon
Requestor: Mark Amrhein, Parametrix Inc.
Material: Unscreened JO-GRO co-compost

Total Addition	pounds per cubic yard:	Cubic yards per 1,000 square feet: 1	2	3	4	5	6	7
nitrogen	10.998	11.0	22.0	33.0	44.0	55.0	66.0	77.0
P_2O_5	7.965	8.0	15.9	23.9	31.9	39.8	47.8	55.8
K_2O	3.887	3.9	7.8	11.7	15.5	19.4	23.3	27.2
iron	2.174	2.2	4.3	6.5	8.7	10.9	13.0	15.2
manganese	0.159	0.2	0.3	0.5	0.6	0.8	1.0	1.1
zinc	0.148	0.1	0.3	0.4	0.6	0.7	0.9	1.0
copper	0.075	0.1	0.1	0.2	0.3	0.4	0.4	0.5
boron	0.008	0.0	0.0	0.0	0.0	0.0	0.1	0.1
calcium	7.228	7.2	14.5	21.7	28.9	36.1	43.4	50.6
magnesium	1.530	1.5	3.1	4.6	6.1	7.6	9.2	10.7
sodium	0.324	0.3	0.6	1.0	1.3	1.6	1.9	2.3
sulfur	2.043	2.0	4.1	6.1	8.2	10.2	12.3	14.3
molybdenum	0.00111	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Pounds of nutrients per above application rate.						
Salinity if incorporated 6" deep		0.34	0.68	1.02	1.36	1.70	2.04	2.38

Total Addition	pounds per ton:	Tons per acre: 1	3	5	8	10	12	15
nitrogen	31.46	31.46	94.38	157.29	251.67	314.59	377.50	471.88
phosphorus	22.78	22.78	68.35	113.92	182.27	227.84	273.41	341.76
potassium	11.12	11.12	33.36	55.59	88.95	111.18	133.42	166.78
iron	6.22	6.22	18.66	31.09	49.75	62.19	74.62	93.28
manganese	0.45	0.45	1.36	2.27	3.63	4.53	5.44	6.80
zinc	0.42	0.42	1.27	2.12	3.39	4.24	5.08	6.35
copper	0.21	0.21	0.64	1.07	1.71	2.14	2.56	3.20
boron	0.02	0.02	0.07	0.12	0.19	0.24	0.29	0.36
calcium	20.68	20.68	62.03	103.38	165.41	206.77	248.12	310.15
magnesium	4.38	4.38	13.13	21.88	35.00	43.75	52.51	65.63
sodium	0.93	0.93	2.78	4.64	7.43	9.28	11.14	13.92
sulfur	5.84	5.84	17.53	29.22	46.75	58.43	70.12	87.65
molybdenum	0.00	0.00	0.01	0.02	0.03	0.03	0.04	0.05
		Pounds of nutrients per above application rate.						
Salinity if incorporated 6" deep		0.02	0.07	0.11	0.18	0.22	0.27	0.33

bulk density, pounds per cubic	699
salinity millimho/cm	6.28