SITE SELECTION STUDY FOR A NEW SANITARY LANDFILL FOR THE SUBIC BAY METROPOLITAN AUTHORITY, OLONGAPO, PHILIPPINES

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SUMMARY: The Subic Bay Metropolitan Authority (SBMA) was created in 1992, after the United States Navy closed down its operations. The former US Naval Base was converted to a freeport zone, utilizing the facilities left by the US Navy. In order to keep up with the demand of a growing enterprise zone, SBMA endeavored to ensure that adequate basic services were maintained, including solid waste management. To this end, SBMA executed a contract to evaluate sites within the freeport zone as potential sanitary landfill facilities. A siting study was conducted that evaluated 13 potential sites and narrowed those sites down to three for detailed geologic, hydrologic, and engineering evaluations. Based on the detailed evaluations, one site was recommended for development as a sanitary landfill. In early 2001, a detailed design and master development plan were initiated for the selected site.

1. INTRODUCTION

The SBMA was created in 1992, after the US Navy closed down its operations. The former US Naval Base was converted to a freeport zone, utilizing the facilities left by the US Navy. The Subic Bay Freeport Zone (SBFZ) has enjoyed tremendous success and economic growth, outweighing the financial and economic benefits that the former naval facility provided to Philippine citizens in terms of jobs and employment. In order to keep up with the demand of a growing enterprise zone, SBMA must ensure that adequate basic services are maintained, including solid waste management.

The existing landfills within the SBFZ will reach their design capacities in approximately 2003, according to SBMA personnel. This created the need to plan for new facilities. Along with this planning, SBMA proposed to utilize the current state of practice and industry standards in siting, designing, constructing, and operating its solid waste management facilities. The design of a modern sanitary landfill will ensure the safety and well being of the workers, residents, and locators at SBMA and the planned service area. It will also protect the valuable natural resources and the general environment of the SBFZ as a whole.

It was the intent of the study to site and plan for a facility that will be able to serve other surrounding cities and municipalities within the influence and boundaries of the Subic Special Economic Zone as defined by the Philippine Republic Act 7227 of 1991. This included Olongapo City, Castillejos, San Marcelino and Subic in the province of Zambales, and Dinalupihan, Hermosa, and Morong in the province of Bataan. Initially however, the landfill will serve the SBFZ only until such time that an arrangement (political, financial, and legal) is developed and executed among SBMA and the other jurisdictions for the common use of the site, as a regional facility.

The siting study for a new sanitary landfill was comprised of the following components: development of a baseline for landfill planning, developing site selection criteria, identifying potential landfill sites, selecting three candidate sites, and conducting topographic mapping, subsurface investigations, hydrogeologic characterizations, and developing conceptual landfill plans and costs for the three selected sites. In conjunction with the siting study, an initial environmental evaluation was also conducted on the three narrowed down sites.

2. BASELINE FOR LANDFILL PLANNING

Determining the baseline for landfill planning consisted of many different tasks. These tasks included identification of potential service areas, significant population centers, large waste generators, and existing/potential waste diversion techniques. The climatic data for the surrounding area was also obtained. The most important part of the landfill planning task consisted of a waste generation feasibility study.

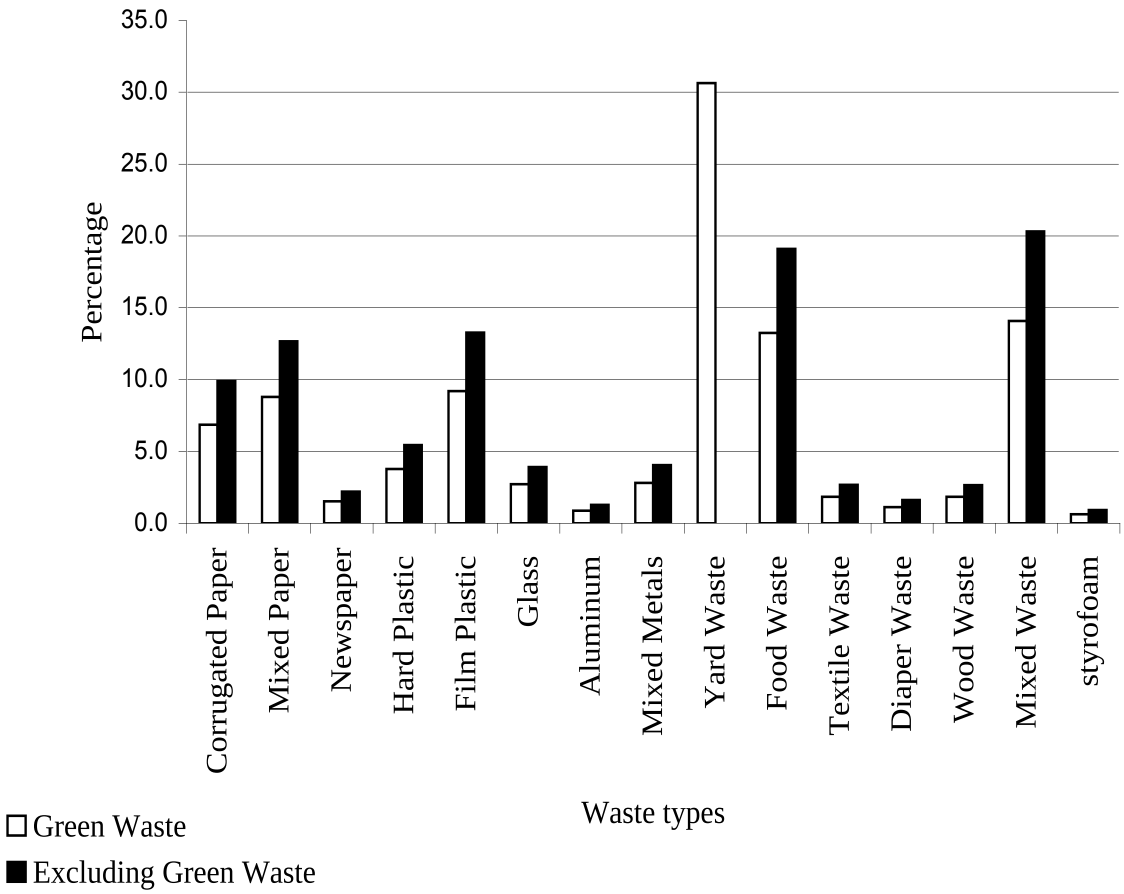
The waste generation feasibility study was performed by utilizing both a field waste sorting program and a literature and records review of the affected landfills. Information characterizing each affected City and Municipal jurisdiction was also reviewed and incorporated into the final report. The cities and municipalities within the boundary of the SBEZ include the Subic Bay Freeport (SBF), the City of Olongapo, and the municipalities of Subic, Castillejos, San Marcelino, San Antonio, Morong, Hermosa, and Dinalupihan. The purpose of this investigation was to develop an accurate representation of the waste generation of the SBF and other cities and municipalities within the possible service area.

The results of the study found that the total number of industrial waste generators within the Freeport Zone is expected to increase from the existing 319 to 1,047 by the year 2015. This increase will result in an increase in waste disposal needs from the existing 76,448 cubic meters to approximately 247,440 cubic meters in 2015.

The Waste Characterization Study resulted in the categorization of wastes by type arriving at the landfill. A quantitative evaluation of SBMA collection trucks was performed, supplemented by a qualitative evaluation of private and authorized haul vehicles. The findings of the quantitative portion of the study showed that the majority of waste arriving at the landfill for disposal consists of green and yard wastes, food wastes, and mixed wastes. The qualitative evaluation of the private and authorized haul vehicles found that the majority of wastes received were construction/demolition wastes and green/yard wastes. Figure 1 shows the breakdown of materials by waste type.

A general review the affected municipalities was also performed to define the current waste management practices and the current waste generation quantities. This information was incorporated into the total waste generation estimates expected for the new landfill.

Figure 1
Subic Bay Metropoliton Authority
Packer Collection Vehicles
Waste Classification



3. DEVELOP SITE SELECTION CRITERIA

A total of 13 potential landfill locations were identified in and around the Subic Bay Freeport Zone. In order to determine the suitability of each of the sites as a landfill, the Project Team developed a list of site selection criteria. This list was developed from the Team's personal experience in landfill siting, "Sanitary Landfill Design and Siting Criteria" developed by Sandra Cointreau-Levine provided in the Terms Of Reference (TOR) document, the "Landfill Site Identification and Screening Criteria for Local Governments" by DENR, and from the Handbook of Landfill Operations by Neal Bolton, P.E. (1995).

The list of site selection criteria developed includes the following items:

- Ownership/Acquisition
- Zoning

- Road Access
- Topography
- Capacity
- Soils
- Depth to Groundwater
- Proximity to Water Wells
- Surface Water
- Flood Hazard
- Airport Safety
- Holocene Faulting
- Seismic Impact zone
- Site Stability
- Run-On/Run-Off Controls
- Landfill Gas Control
- Land Use
- Agricultural Land
- Habitat Value
- Visual Impacts
- Downwind Impacts

All of the above criteria are important in the development of a sanitary landfill. Some criteria, however, are more important than others. To account for this, a multiplier was assigned to each of the criteria. While many of the above criteria can be mitigated via engineering solutions, some criteria can result in a fatal flaw to the successful development of a landfill. Such items as Holocene faulting, airport safety, flood hazard, stability, and habitat value could result in the potential landfill site being rejected. The total score of each potential landfill site was developed by adding the individual scores for each criterion. The three sites with the highest scores were then selected for further study.

4. SELECT THE THREE HIGHEST RANKING SITES

After all 13 sites were identified, a reconnaissance and inspection survey was conducted for each location. Each element of the evaluation criteria was used as a guide to make a judgment on the character of each site. After a compilation of field notes from the reconnaissance inspection, corresponding scores were assigned to each site for each criteria element, as described in the previous section.

Distances from each service area to each individual potential site were estimated using available maps. All distances were measured in kilometers. This information was used to evaluate access to each site and later, when evaluating transportation access to each of the three narrowed down sites under several transportation scenarios such as direct hauling or transfer hauling.

The availability of each of the potential landfill sites was evaluated. This involved a review of government records to determine the ownership, zoning, and future planning involved with the site. Sites with prohibitive land use restrictions were eliminated from consideration.

Estimates of each of the 13 sites' air space, capacity, and life were determined using existing available topographic maps and reasonable standard assumptions on landfill configuration, excavation quantities, cover quantities, and refuse volume and density. Preliminary areas (hectares), volume capacities (cubic meters) and landfill life (years) estimates were determined under two scenarios: SBFZ as the sole service area; and SBFZ with the other municipalities as the service area.

The life estimates include growth considerations over each site's estimated life. Air space was estimated using the average end-area method. A rough configuration of a landfill was developed, using a reasonable average sideslope of 10%, the resulting average landfill depth based on this slope, and an average excavation depth of at least 25% of the average landfill height. This assumption is based on a cover to refuse ratio of 3:1, hence the excavation requirement for soil cover should at least be 1/4 of the landfill volume. This should, therefore, represent an equivalent excavation depth of at least equal to 1/4 of the average height.

At the conclusion of the site ranking evaluation, the total adjusted scores for all of the criteria were summed for each of the potential landfill locations. Based on the ranking, three sites were recommended out of the original 13 evaluated. These sites were Site 2: East of Morong Gate, Site 6: North of Tipo Road Security Plaza, and Site 12: Valley Near Familiar Peak. With the concurrence of SBMA on the recommended sites, the Project Team began detailed investigations on the three narrowed down sites.

5. DETAILED EVALUATION ON THREE NARROWED DOWN SITES

5.1 Topographic Surveys

Topographic surveys of the three selected sites (2, 6, and 12) were conducted from February 2000 to April 2000. The topographic survey was conducted using a total station with electronic fieldbook. A total plan area of 210.3 hectares was surveyed for the siting study. To get an accurate topographic map, the existing topography was surveyed at a grid of 10 – 20 meters depending on variations of the ground surface. Man-made features included in the survey consisted roads, bridges, structures, test pits, boreholes, and fences. All major natural features, such as rivers, streams, and trees (diameter > 0.25 m) were also included.

5.2 Sub-Ground Investigations

The sub-ground investigation phase of the siting study was one of the most critical aspects in determining the technical suitability of an individual site as a sanitary landfill. The sub-ground investigations conducted during the siting study included geologic, geotechnical, and hydrogeological evaluations. The characterizations included drilling and logging boreholes, excavating and drilling test pits, field and laboratory analysis of earth materials, and observation of the geologic and hydrogeologic conditions.

Regional geology in the Subic Bay area consists of Pliocene and Quaternary volcanic deposits that have been weathered to residual soil near the ground surface. Volcanic deposits are predominantly volcanic tuff and breccia, with some rhyolite and andesite. Specifically, the Subic-Olongapo area principle mountain masses are composed of harzburgites, dunites, gabbros and troctolites (G. P. Yumul et al., 1998). The degree of induration, welding, mineral composition, texture and rock quality vary significantly due to the close proximity to volcanic activity. On the ground surface, volcanic ash from the recent eruption of Mount Pinatubo covers the ground where the surface is protected against erosion. Residual soils consist of clay, silt and mixtures of sand and clay or silt. The major constituent of the clay materials is kaolinite.

A field investigation was conducted at the three narrowed-down potential landfill sites in order to characterize the subsurface soils and hydrology for conceptual design purposes. The field exploration program was performed from January 26 to March 1, 2000, and consisted of drilling 3 borings per site to depths up to 20 meters below the ground surface, and digging numerous test pits to a depth of 2 meters.

Borings were advanced using a wash boring drill, equipped with a water pump, drill rods, and tripod. A water pump was used to force water down the center of the drill rods, and cuttings were forced up the borehole to the ground surface with the water circulation. Rock coring equipment was used to advance the boreholes in unweathered or hard rock material.

Samples were taken from the boreholes at 1-meter intervals in weathered soil and a continuous core was extracted in the unweathered materials. Soil was sampled using a standard split spoon, with an outside diameter of 5.1 centimeters. The sampler was driven into the soil at the bottom of the borehole by means of hammer blows. The hammer weighed 63.5 kilograms and was dropped a distance of 76.2 centimeters. The hammer blows were applied at the top of the drilling rod. The sampler was driven a total distance of 45.7 centimeters, and the number of blows was recorded for each interval of 15.2 centimeters. The sum of the number of blows required for driving the last two 15.2-centimeter intervals is referred to as the standard penetration number, N. The standard penetration number is commonly used to correlate several physical parameters of soils, such as the consistency of clays or the density of sands.

Soil and rock samples obtained in the standard split spoon were visually classified and cataloged by our engineers and geologists, and selected samples were designated for classification and laboratory testing. The soils were classified in the field in general accordance with ASTM D 2488, and in the laboratory by ASTM D 2487, commonly referred to as the Unified Soil Classification System (USCS).

After the borings were drilled to depth, they were completed as groundwater monitoring wells. The wells were constructed with manually slotted Schedule 40 PVC pipe with a nominal well diameter of 5 centimeters, and the annulus around the pipe was filled with coarse sand. Near the ground surface where the pipe was solid, the annulus was sealed with a bentonite plug and finished off with cement grout around an iron well casing. Security locks were placed on all of the protective iron covers.

Test pits were excavated to depths up to 2 meters below the ground surface using a pick and shovel. Samples were taken at 0.5-meter intervals. The soil profile in each test pit was visually classified and cataloged by Project Team engineers and geologists, and selected samples were designated for classification and laboratory testing.

All soils testing on the materials obtained from the borings and test pits was performed in general accordance with the latest version of the American Society for Testing and Materials (ASTM) test methods where applicable. The laboratory tests that were conducted during the siting study are summarized in Table 1.

Table 1 - Summary of Laboratory Tests Performed

Test Description	Number of Tests Performed
Atterberg Limits (ASTM D 4318)	44
Sieve Analysis (ASTM 136)	46
Moisture Density Relationships (ASTM D 698)	8
Flexible Wall Permeability, Remolded (ASTM D 5084)	6
Flexible Wall Permeability, Undisturbed (ASTM D 5084)	5
Large Scale Direct Shear Test (ASTM D 5321)	3
Triaxial Shear (ASTM D 2850)	3
X-ray Diffraction Testing, Powder Mount	3

The materials encountered during the field investigation consisted of quaternary volcanic deposits. The upper soil materials encountered near the ground surface were composed of silt, silty sand and clayey sands. Since the 1992 eruption of Mount Pinatubo, all sites contained a thickness of grey volcanic sand that varied between 1 cm and 11.5 cm, depending on the slope and thickness of vegetation. Below these upper soils were various types of extrusive volcanics including tuffs, breccias, rhyolites and andesites. Because of the close proximity to volcanic activity, a large variation of rock types was observed. The degree of induration, welding, mineral composition, texture, and rock quality also varied significantly.

5.3 Monitoring Well Installation and Sampling

From February 26 to March 1, 2000, nine monitoring wells were installed to determine the hydrogeological characteristics of the three narrowed-down landfill sites. Included in this study was the determination of the background characteristics of the existing groundwater conditions. These wells were installed to obtain groundwater samples and hydrogeologic information.

The Project Team constructed all the wells using a nominal 6-cm diameter, schedule 40 polyvinyl chloride (PVC) pipe. Using a portable drill rig and a tripod constructed of drill rods, the borings were cleaned using high-pressure water that was forced down into the hole to rinse excess cuttings. The maximum depth for any of the wells was 20 meters. The bottom pipe sections were hand slotted with a hacksaw (2-mm wide slots), the bottom plug was glued on, and the glued sections of pipe were lowered into the open borehole. In some instances, a bottom "plug" was constructed by cutting, folding and heat welding the bottom of the pipe to seal it and form a plugged end.

Groundwater levels and borehole depths determined the length of slotted versus solid pipe. Generally, the slotted PVC sections started at the bottom of the boring and ended one to two meters above the water level that was encountered at the time of drilling. During the overall time of drilling and well setting, there was typically a groundwater drop of approximately 0.25 to 0.5 meters. Construction duration for the completion of each monitoring well installation was one to two days.

The wells all included a fine to medium gravel and bentonite annulus backfill with coarse sand being used between the gravel and bentonite in those wells with very shallow groundwater. Both the gravel and the sand were poured over the slotted pipe prior to placement in order to insure that the materials would not pass through and potentially fill the annulus inside of the well. Cement grout was used as the ground surface cap and as the setting for the locking iron protective well cover. Well development was performed after the cement grout had set.

Prior to well purging and the retrieval of groundwater samples, all wells were cleaned and developed using a 1.0-liter Teflon bailer. The wells were developed by bailing out a volume of water greater than three (3) times the static water volume in the well. The maximum volume in any one well was less than or equal to 47 liters. Each of the sites required the use of one bailer, which was rinsed with clean water prior to sampling the next well.

Immediately prior to obtaining the water quality samples, each well was purged of six (6) bailer volumes to remove any stagnant water. After purging, and during each bailer volume removed from the well, the pH, conductivity and temperature were taken and recorded to insure that the water had stabilized prior to placement into the sample bottles. Five (5) containers were used per well site and surface water sampling location. Each of the containers was properly labeled with the site and sampling location, date, time, and, for the wells, water depth. Photographs were also taken at each sampling location.

Once the samples were properly retrieved, the bottles were placed in coolers, which contained ice to preserve them. No chemical preservatives were required in the bottles based on the short time necessary for transport to the laboratory and the type of analysis required. Prior to transporting the samples from the site to the laboratory, a chain of custody was completed for the samples. The chain of custody form included the date, time, sample number, site location, analysis required and number of containers per site.

5.4 Development of Conceptual Plans

Information obtained from the field investigations, document review, and surveys were used in the development of conceptual plans for each of the sites. Engineering analyses were also performed during preparation of the plans to ensure that each landfill was designed appropriately.

The locations of the facilities and the landfill area for each site were based on the topography, anticipated traffic patterns, location of existing roads, streams, etc. It was presumed that grading requirements would be similar for each of the sites. All liner excavation and fill side slopes were designed at 3 to 1, horizontal to vertical. The bottom grades were chosen based on depth to groundwater and landfill stability requirements. The bottom liner for each site would be a composed of a composite of various manmade and natural materials consisting from top to bottom of:

- A 600 mm thick operations layer;
- A geotextile filter fabric;
- A 300 mm thick sand drainage blanket or geocomposite LCRS;
- A 1.5 mm textured high density polyethylene (HDPE); and
- A 600 mm thick prepared low permeability soil subgrade.

The blanket leachate collection and recovery layer was designed to drain to a collection sump located at a central point at the down gradient end of the landfill. The sump would be constructed with collection pipes and risers to allow extraction of leachate from the lined landfill cell. No penetrations have been designed into the liner system to minimize the potential for leakage of contaminated leachate from the landfill. Leachate will likely be recirculated back into the landfill to promote rapid degradation of the waste. This method of treatment has been successfully used in Asia, Europe, and the U.S. to reduce the organic contaminant levels that would normally be present at closure. Temporary holding ponds will likely be required during operations to provide more flexibility in the handling and treatment of leachate. In the event that excess leachate cannot be recirculated, other treatment options will have to be explored for the final selected site. The leachate management system would likely remain operational throughout the post-closure period.

Methane and other gases will be generated as the waste degrades within the landfill mass. During the initial stages of development, the amount of gas generated will be minimal. This minor amount of gas will be controlled by the placement of daily cover soil. However, as the site is filled, gas generation will increase to a point where the soil can no longer control gas and odors. Gas collection facilities would then be constructed. These facilities would likely consist of collection wells and a flaring station. As with the leachate management system, the flaring station would likely be operated throughout the post-closure period.

For design of the final fill plan, the waste was presumed to be placed in multiple, compacted lifts with daily soil cover. When an area reaches its final grade, intermediate cover (300 mm thick) would be placed to minimize infiltration of rainfall and to prevent infestation by insects, rodents, or other disease vectors until final closure construction. The top cap of each landfill was graded at an approximate slope of 3% with side slopes constructed at 3 to 1. Surface water drainage benches were laid out at 10 meter to 15 meter vertical intervals on the side slopes where the landfill height was in excess of 30 meters. Berms were provided on the top cap to divert water to collection ditches and downdrains to transport water off of the cap. Access to the cap was provided by several roads positioned at various locations around the facility.

The final fill heights for each site were chosen based on the size of the site and landfill stability requirements. The cover design is based on U.S. standard of practice utilizing a vegetative/protective cover layer and a drainage layer overlying a low permeability infiltration barrier. The cover for each site will be similar to the bottom liner and be composed of a composite of various manmade and natural materials consisting from top to bottom of:

- A 600 mm thick vegetative/protective cover layer;
- A 300 mm thick sand drainage blanket or geocomposite;
- A 1.0 mm geomembrane; and
- A 600 mm thick intermediate cover and foundation layer.

At closure, the cover would be seeded as necessary to promote revegetation to minimize erosion and potential damage to the cap. Additional gas collection wells, etc. were assumed to be reconstructed to tie into any existing flaring station.

The conceptual plans that were developed for each of the three selected sites include the following drawings:

- Title Sheet and Site Location Map
- Existing Conditions – showing site topography and borehole locations;
- Liner Grades - showing the proposed facilities (gatehouse and weighbridge), limits of the lined landfill and excavation grades;
- Fill Plan – showing the final grades of the landfill after filling and closure;
- Cross Sections – showing the bottom liner and fill lines; and
- Details – showing the liner, leachate collection system, cover system, road, and drainage structures.

6. CONCLUSION

As part of the preparation of the conceptual design plans, the Project Team conducted preliminary engineering evaluations. These evaluations included the development of seismic criteria, performing slope stability analyses, determining potential leachate generation, and performing a surface water drainage analysis. These analyses and evaluations were extensive, and as such, are the subject of future papers.

Based on the economic, environmental, social, and engineering evaluations conducted at the three narrowed down sites, the Project Team recommended Site 6 for further detailed design. Site 6 was the apparent, most suitable and cost-effective site, and was recommended for detailed design and development as a New Sanitary Landfill for SBMA. The factors included in the decision include access, sparse vegetation, topography, location, on-site soils, and run-on/run-off controls.

In addition, the Initial Environmental Evaluation determined that there would be little interference with local human habitation or any protected or endangered flora and fauna. The one concern voiced by SBMA involved the proposed construction of the visitor's center and customs area that is located near the entrance to the site. A subsequent meeting with SBMA resulted in a discussion of access routes and an understanding of the need to work together on the detailed design to ensure that the two projects are compatible.

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