'The challenges of introducing native species and developing a natural succession woodland structure have been hard to meet due to the exposed site which is critically short of soil water. However, careful woodland management, thinning of plantation species and assisted introduction of native species, should allow for a gradual and continued evolution, whereby the knowledge obtained through planting trials during the operation stage can be fully utilised.'

Barry Wilson

Trials in succession woodland planting at SENT Landfill, Tseung Kwan O

Barry Wilson

Site of SENT Landfill and adjacent Tseung Kwan O Industrial Estate

Background

There are currently just three operating landfill sites in Hong Kong following the closure of the thirteen other sites between 1975 and 1996. SENT Landfill, the 3rd landfill site in Tseung Kwan O, receives about 35% (2012 figure) of the total waste generated in Hong Kong and is operated by Green Valley Landfill Ltd, a subsidiary of the Veolia Environmental Services Group contracted for the design, construction and operation of the landfill for the Environmental Protection Department of Hong Kong SAR Government.

The landfill is fast approaching capacity and typically landscape restoration works would be undertaken at closure. However planting at SENT has been undertaken as an ongoing process ever since the commencement of progressive restoration. The Restoration Masterplan, was developed by consultants Urbis Ltd prior to letting of the works contract and the operator, contracted to manage for a further 30 years following its closure, will ensure ongoing maintenance and management of the facility. Ultimately the facility is intended for passive recreational use, with its position abutting the Clearwater Bay Country Park making it a potentially valuable public asset.

Initial planting was undertaken in 1997 on the first fill slopes formed around the base of the site area. Subsequently, restoration planting has been undertaken during the planting season more or less on an annual basis as each section of the landfill has been completed. The Restoration Masterplan essentially envisaged the creation of three types of native vegetative cover; woodland; scrubland; and grassland, with the objective of creating a natural system promoting wildlife and nature conservation through colonisation and natural succession, ultimately achieving a climax woodland community.

2003 - Restoration Phases 1-4. Phased planting blocks can be clearly identified as the landfill grows.

Current Active Landfill Sites in Hong Kong

Landfill	Location	Ha	Opened	Capacity
West New Territories Landfill (WENT)	Nim Wan, Tuen Mun	110	1993	61 million m³
South East New Territories Landfill (SENT)	Tai Chik Sha, Tseung Kwan O	100	1994	43 million m³
North East New Territories Landfill (NENT)	Ta Kwu Ling, North District	61	1995	35 million m³

Early Trials

The masterplan called for a series of planting trials in the initial phases of the restoration, the objective being to identify at an early stage which plant species and soil media would be most effective at promoting growth. With approximately 1.5million m³ of soil required for the landfill it was considered imperative that as much material could be found on site as possible. Small amounts of site stripped topsoil and Completely Decomposed Volcanics (CDV) were available for re-use however early trials looked at the possibilities of utilising Construction and Demolition Fines (CDF) which would be available through the duration of the landfill development at an appropriate scale. CDF are principally composed of gravelly / sandy particles with high pH (9.0) and potassium content. Once ameliorated, the medium offered good possibilities of undertaking large scale sustainable planting. Initiated in April 1997, twelve trial blocks were established to test variations in soil amelioration, planting spacing and methods. The plant performance was monitored over the next 6 years (until 2003) by the Department of Applied Biology and Chemical Technology at The Hong Kong Polytechnic with the Institute for Natural Resources and Waste Management and Department of Biology at Hong Kong Baptist University. The results obtained helped influence decision making for the following planting seasons.

Early Results with Soil Mixtures

The early attempts to manufacture a growing medium were based on a 1200mm layer of CDF over the polyethylene cap layer, with an ameliorated top layer up to 300mm deep. Ameliorants included horse and pig manure, shredded recycled wood products and regular horticultural products. Survival rates for tree seedlings were variable and it was hard to draw clear conclusions of one ameliorant over another, however it was apparent that seedling survival rates were severely affected by the extent of amelioration, with no apparent benefit being identified where ameliorants were limited to the immediate rooting zone of the individual (200x200mm) plant pit.

A change in the planting mixes to hardier species was adopted and the Second Year Plant Performance Report demonstrated that the use of leguminous species, in both improving soil structure and showing good survival characteristics, was beneficial. This suggested that more use of *Caesalpinaceae*tree species could be successful, eg. *Bauhinia, Cassia, Delonix* and *Peltophorum*.

The ongoing problems with low soil water content

Whilst continual watering of seedlings during establishment may have been adequate during the first year of growth, once the establishment period ended and watering was suspended survival became problematic. Only the plantation species seemed able to cope with the water stress on the site and a longer term approach to soil water content needed to be addressed if any success with growth of non plantation species was to be achieved.

The use of water absorbent polymers within the plant pit was considered but not utilised due to the fact that the major problem appeared to be the difficulty of getting roots to leave the extent of the planting pit, and the polymers could not be applied consistently throughout the top layer.

The conclusion was that a significant change to the topsoil structure would be required to promote success in developing non-plantation species within the restoration. The 1500mm deep planting medium structure was revised to be 300mm CDF covered with 1200mm CDV compacted to 95% MDD. The CDV material was initially available on site, having been stripped and stockpiled during site formation. Whilst it was not in sufficient quantities to last for the duration of the landfill it was considered beneficial to utilise the material whilst it was available.

2014 - Erosion problems have affected the success of hydroseeding in some areas. Newly planted delicate species in microclimatic growth tubes can be seen with early phase woodland in the background.

Subsequently imported soil material from various sources has been used for the 1500mm deep planting medium. Use of CDF was suspended once the construction waste sorting plant was no longer on the landfill. For the top 300mm, CDV has been used which is of a similar nature to that excavated on site.

Trials in species mix and arrangement

Over the following years between 1998 and 2003 restoration was carried out utilising variations of tree species within the planting matrices. Whilst the overall greening appeared to be satisfactory, on closer inspection the species diversity within the tree groups was still well below that desired. Nurse species were expected to make up about 60% of the cover at this stage, however due to the failure of the more delicate species they numbered more than 90%. In planting Phase 4, *Schima, Castanopsis, Cinnamomum* and *Machilus* in particular, all struggled to survive even in the sheltered south east area of the landfill. As a result the balance of plantation species was increased from Phase 6 onwards by adding a second nurse species in order to increase both the degree of shelter provided and the physical amount of greening. Those species directly down slope from the blocks of fast growing nurse species were observed to thrive most successfully. This was considered to be due to the increased shelter from wind and sun afforded to them. In particular nurse species at the bottom side of a block appeared to be redundant. As such the matrices were amended to attempt to provide more and smaller pockets of sheltered planting areas by increasing the distribution of nurses through the block.

The good performance of *Albizia lebbeck* in phases 3 and 4 recommended it to more extensive use on the landfill whilst *Aleurities* and *Gardenia* species also demonstrated acceptable performance. Poor success in establishment was noted from the following species:

- *Alnus formosana*
- *Celtis tetranda*
- *Cratoxylum ligustrinum*
- *Eucalyptus torrelliana*
- *Ficus hispida*
- *Ficus superba*
- *Gordonia axillaris*
- *Itea chinensis*
- *Liquidambar formosana*
- *Litsea rotundifolia*
- *Macaranga tanarius*
- *Mallotus paniculata*
- *Phoenix hanceana*
- *Pandanus tectorius*
- *Quercus edithae*

In general it became apparent that a balanced block matrix mix would be made up of six species based on the following :

1. *Acacia* spp. – from *A. confusa* / *A. auriculaeformis* / *A. mangium*

2. Secondary nurse – from *Eucalyptus citriodora* / *Casuarina equisetifolia* / *Cassia surratensis* / *C. siamea* / *Lophostemon confertus* / *Hibiscus tiliaceus*

3. Tertiary nurse - *Albizia lebbeck* / *Calliandra haematocephala* / *Delonix regia*

4. Native species A – (aggressive) – *Cinnamomum* spp. / *Litsea glutinosa* / *L. monopetala* / *Ficus microcarpa* / *F. benjamina* / *Celtis sinensis*

5. Native species B – (delicate) – *Schima* / *Machilus* / *Schefflera* / *Castanopsis* / *Sapium* / *Ficus virens*

6. Protected species – *Magnolia grandiflora* / *Largerstroemia indica* / *L. speciosa* / *Rhododendron simsii* / *Ailanthus fordii* / *Rhodoleia championii* / *Camellia* spp. (not *C. japonica*)

Phased planting currently being undertaken has essentially followed the 6 species block matrix utilising clustered blocks of 25 plants spaced at 1500mm with some revisions to the species included above.

2014 - Restoration phase 9. One year into establishment. Phase 7 planting blocks can bee seen at the rear.

Introduction of microclimatic growth tubes

Following the continued disappointing results in establishing native trees within the restoration, a new approach has been considered since the 7th phase of planting (undertaken in 2010) whereby approximately 10% of plants were installed with microclimatic growth tubes (MGTs), as a trial. A detailed review was carried out in August 2011 to ascertain the effect of the tubes and whilst there were some positive indications for some species, the conclusions were hard to draw due to the small sample size. As such, wider and more stringent trial monitoring has now been established over the last three planting phases combined with the introduction of weed mats.

Early indications are that mortality rates do appear lower for plant species planted with MGT's against those without, however the percentage difference often appears minor for some species, making it difficult to justify the extra cost. Further trials are looking at specific species that might best benefit from the addition of tubes in combination with the use of weed mats as well as critical watering at key times after planting. What has been observed however is the clear differentiation in size between seedlings, where tubed material is consistently larger and more robust in health. It would also appear that many of the delicate species, such as *Ilex asprella*, are unable to successfully establish on the landfill without the assistance of MGT.

Maintenance issues

Large numbers of invasive *Leucaena leucocephala* have become an increasing problem on the landfill in recent years, taking a hold on both temporary fill areas and final restoration slopes. They are particularly problematic in areas of tree planting as they colonise en-masse, compete with seedlings for the valuable soil water and crowd out new plantations. If not continually removed at the earliest possible moment their removal becomes increasingly difficult as they become too large to be pulled by hand. Whilst they were initially viewed positively in their ability to colonise the landfill, their profuse seeding is now a major concern.

2010 - Woodland planting about 10 years old. Leucaena has started to invade the light pockets and woodland margins.

2014 - Restoration phase 9. 1500mm planting medium being graded for future planting phase

2004 - A mixed canopy established. Grass cutting can be suspended and the woodland left to develop.

Conclusion

Continual restoration planting at SENT has ensured that the visual quality of the landfill has been significantly improved during its operation. Initial tree planting has now developed into a tall and dense canopy, giving a positive green image around the development and integrating with the surrounding environment. The ecological makeup is similar to that of the surrounding plantation woodlands contained within the Country Park areas, with a variety of invasive flora and fauna having been increasingly identified.

The challenges of introducing native species and developing a natural succession woodland structure have been hard to meet due to the exposed site which is critically short of soil water. However, careful woodland management, thinning of plantation species and assisted introduction of native species, should allow for a gradual and continued evolution, whereby the knowledge obtained through planting trials during the operation stage can be fully utilised.

Barry Wilson is a landscape architect, urbanist and university lecturer. His practice, Barry Wilson Project Initiatives, has been tackling urbanization issues in Hong Kong and China for over 20 years.

www.initiatives.com.hk

Project Team

Client – Environmental Protection Department

Operator – Veolia Environmental Services Group

Landscape Masterplan – Urbis Ltd.

Independent Consultant – Meinhardt Infrastructure and Environment Ltd.

Landscape Independent Checker – Barry Wilson Project Initiatives Ltd.

2004 - Weed suppression in planting blocks is essential in the early years of woodland development

Bibliography

1. Carnevale, N.J. & Montagnini, F. 2002. Facilitating regeneration of secondary forests with the use of mixed or pure plantations of indigenous tree species. Forest Ecology and Management 163: 217–227.

2. Chong, S.L. 1999. Restoration of degraded lands in Hong Kong. In M.H. Wong, J.W.C. Wong & A.J.M. Baker, eds. Remediation and management of degraded lands. Boca Raton, London, New York, Washington, DC, Lewis Publishers. 185–193

3. Coomes, D.A. & Grubb, P.J. 1998. Responses of juvenile trees to above- and below-ground competition in nutrient-starved Amazonian rain forest. Ecology 79(3): 768–782.

4. Corlett, R.T. 1999. Environmental forestry in Hong Kong: 1871–1997. Forest Ecology and Management 116: 93–105.

5. Haggar, J.P., Briscoe, C.B. & Butterfield, R.P. 1998. Native species: a resource for the diversification of forestry production in the lowland humid tropics. Forest Ecology and Management 106: 195–203.

6. Hau, B.C.H. 1999. The establishment and survival of native trees on degraded hillsides in Hong Kong. (Doctoral thesis), The University of Hong Kong, Hong Kong.

7. Hau, B.C.H. 2000. Promoting native tree species in land rehabilitation in Hong Kong, China. In S. Elliott, J. Kerby, D. Blakesley, K. Hardwick, K. Woods & V. Anusarnsunthorn, eds. Forest restoration for wildlife conservation. International Tropical Timber Organization and The Forest Restoration Research Unit, Chiang Mai University, Thailand. 109–120

8. Lai, P.C.C. and Wong, B.S.F. 2005. Effects of tree guards and weed mats on establishment of native tree seedlings: implication for forest restoration in Hong Kong, China. Restoration Ecology13 (1): 138-143.

9. Lay, C.C., Chan, S.K.F. & Chan, Y.K., 1999. The utilization of native species in local afforestation programme. Agriculture and Fisheries Department, the Government of the Hong Kong SAR. (unpublished)

10. Richardson, D.M. 1998. Forestry trees as invasive aliens. Conservation Biology 12(1): 18–26.

11. Zhuang, X.Y. & Corlett, R.T. 1997. Forest and forest succession in Hong Kong, China. Journal of Tropical Ecology 14: 857–866.

12. Zhuang, X.Y. & Corlett, R.T. 2000. Survival and growth of native tree seedlings in secondary forest of Hong Kong. Journal of Tropical and Subtropical Botany 8(4): 291–300. (in Chinese with an English abstract)