Waste not want not – A unique industrial waste disposal facility

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ABSTRACT

Three existing landfills for wastes from Carter Holt Harvey Pulp & Paper, Tasman have or are reaching the end of their lives. These landfills receive primary solids (boiler fly-ash, wood fibre and lime mud – dewatered to 25-30%), secondary solids (slurry of dewatered dredgings from wastewater treatment plant ponds) and dregs (sand, gravel and calcium compounds) are all typical of wastes for pulp and paper plants. New landfill capacity was required for these waste streams starting in 2013. An innovative design was conceptualised and underwent detailed design with the construction of stage 1 of the facility during 2011-2012 earthworks season. At the heart of this innovative design is the concept of retaining one type of waste by using another. In this case using the primary solids to retain the secondary solids utilising tailings dam design principles. This paper looks at the Environmental impact and Risk considerations which were considered in the design and provides an assessment of the operation of the after a year of operation. Design aspects, the current waste streams, the operational aspects and learnings are presented. The innovative design has been accepted by the authorities who have issued resource consents for construction and operation of a new landfill facility which is known as the North Valley Landfill (NVL).

Keywords: landfill, waste, pulp & paper

1 INTRODUCTION

Carter Holt Harvey Pulp & Paper Ltd Tasman (CHH) operate a Kraft pulp mill at Kawerau in the Bay of Plenty, New Zealand. As part of the production process, solid wastes are generated that require disposal. In 2009 it was identified that new long term disposal facilities for the various waste streams were required as the existing facilities were reaching the end of their lives.

A new facility was designed to accommodate the three types of waste streams primary and secondary solids and dregs. The two waste streams discussed in this paper are described below. The design philosophy is discussed together with the assumptions and pilot testing that was undertaken that underpin the design.

2 WASTE TYPES AND DESIGN CRITERIA

The facility receives the following waste types:

2.1 Primary Solids

Primary solids comprise mainly of wood fibre that has dewatered to 25-30% that is derived from the underflow from a clarifier. The underflow is directed through a filter belt press that dewaters the solids which are then stockpiled ready for transport by tip truck to the facility for disposal. Included with the primary solids waste stream are the boiler fly-ash and lime mud. The clarifier treats all the stormwater and mill wastewater from the complex and produces primary solids of a consistent character.

The primary solids waste stream has an average of 30% solids and has a specific gravity of between 0.8 and 1.0. More than 90% of the primary solids are typically less than 1 mm particle size and typically comprises of fibre, lime mud, pumice and fly ash. Shear box testing of the primary solids waste indicated that the geotechnical strength parameters are approximately 20 degrees for internal angle of friction and 2 kPa of cohesion.

Once placed in landfill, the waste allows loss of free water, but being fibrous, the waste has the ability to compact under load (refer to section 3.1 for discussion on compaction). Falling head testing in the existing primary solids landfill indicates that the horizontal saturated permeability rate of the landfilled primary solids is approximately 0.4 m/d (4.6 x 10^{-6} m/s). It is likely that the vertical permeability would be lower when compacted in layers. The issue of biodegradability was investigated and the existing primary solids landfill was subjected to biochemical methane potential (BMP) testing. BMP testing is commonly used anaerobic test method to measure the biodegradability of solid waste. The investigation indicated that the primary solids contained less than 5% of biodegradable material and therefore biodegrability was considered not to be an issue.

2.2 Secondary Solids

Secondary solids comprise a slurry of dewatered dredgings from wastewater treatment plant ponds and consist primarily of settled solids and biosolids (the residue generated by bacterial breakdown of waste as a part of the wastewater treatment process). The dredgings are thickened to around 20% solids prior to disposal. The secondary solids naturally dewater to around 30% solids insitu. Previous disposal in the West Valley site was done by excavating the dewatered dredgings (see Figure 1) and transporting by means of tip trucks.

Figure 1. Dewatered Dredgings

The secondary solids surface cakes easily resulting in cracks that appear on the surface of deposited material. These cracks progressively get filled by additional material that is placed on top of the fill. The resultant fill material is a well pressed and dewatered material with a low permeability. Secondary solids has the potential to behave like a liquid (thixotrophic characteristics) when energy is driven into the material before it has sufficiently dewatered.

Based on literature values for biosolids, the secondary solids permeability is estimated to be between 1 x 10^{-9} m/s to 1 x 10^{-8} m/s. Unfortunately to date no secondary solids have been deposited and therefore no data is available on its settled density or consolidated density.

3 DESIGN PHILOSOPHY

The design of the landfill used the CAE Landfill Guidelines (CAE, 2000) as a general guide and although this publication is aimed at municipal solid waste landfill design, the design guidelines are applicable to ensure a robust and technically acceptable design.

Early in the concept design of the landfill, the idea of using the primary solids to retain the secondary solids was investigated. The differences in the volumes generated between the two waste streams indicated that it was possible to deposit a sizable body of primary solids ahead of depositing the secondary solids. The key to the concept was understanding the characteristic of the waste types. These attributes included the ability of the primary solids to be formed into a stable structure. Laboratory testing of the waste indicated that the primary solids in a compacted state processed suitable shear strength properties. The bulk density of the compacted waste was also considered to be a potential issue.

The use of waste material used to contain the same or other waste material is common practice in the operation of mine waste facilities (commonly called tailings dams). Experience by one of the authors in using coal fines to construct an outer wall to contain coal fine slurry indicated that it was possible to utilise low density materials in this fashion (Strayton & Wates, 1994). This method was first tested at a pilot scale before undergoing full scale testing and upon successful conclusion of these tests, the method was implemented at Rietspruit Coal Mine in the early 1990's. The tailings dam was operated in this manner successfully until the end of its life in 2006.

A further motivation of mono-filling the two wastes was to facilitate reclamation at a later date should a beneficial use be found for one or other of the waste streams.

3.1 Pilot Test

In order to understand the behaviour of the primary solids when utilised as a bulk fill material, a pilot test embankment of primary solids (Figure 3) was constructed at the site of the existing primary solids landfill in 2009. The embankment was constructed from compacted primary solids and left for a period of 6 months. The embankment was visually assessed on a regular basis and examined for any loss in integrity. After this period the embankment was excavated and samples taken to determine the geotechnical properties of the compacted primary solids. The test results indicated that there was no increase in bulk density and shear strength with depth and that the material exhibited the same strength as determined by the laboratory testing. This indicated that the material once compacted retained its density. In situ shear strength testing of the compacted primary solids indicated an average undrained shear strength of 10 kPa with a variability of 2 kPa to 40 kPa. No consolidation testing was done.

During the same period of the primary solids pilot test, the existing secondary solids were investigated on two occasions. The first was during the deposition of secondary solids following dewatering. During this phase the deposited material was in a slurry form and flowed across the previously deposited secondary solids. The freshly deposited area was excavated and it was observed that although the fresh material did not exhibit any substantial shear strength, the previously deposited and drained secondary solids did. It behaved with a soil type shear strength character. The second done a couple of months after the first, indicated that the secondary solids had dried out and that there was no saturated zone within the waste. All free water had been drained through the base of the landfill.

3.2 Design Assumptions

The types and characteristics of the waste streams are described in Section 2 above. The expected annual volumes are given in Table 1. The life of the facility has currently been capped at 35 years and the resource consent has a validity period of 25 years. The main reason for the reduction in volume is improved source control, operation of the clarifier and the division of the primary solids between the various owners of the mill site who now have different landfills.

Table 1: Waste Deposition Volumes (wet Tonnes)

Waste Stream	Estimated tonnage (T/year)	Estimated volume (m^3/year)
Primary Solids (original estimate)	88,000	83,600
Primary Solids (updated estimate – CHH qtys only)	24,600	23,400
Secondary Solids	15,000 (incl water)	3,000[1] (dewatered)
Dregs	6,000	3,500
Notes: [1] – Secondary solids volume after full drainage.		

4 DESIGN

The primary solids landfill (incl boiler ash and lime mud) was designed to fill the upper portion of the main valley of the site with an estimated volume of 3 million m3. The total landfill capacity of the full valley is 8 million m^3. Based on the current revised annual tipping rate, this landfill is estimated to have an overall capacity of approximately 340 years of operation should the entire footprint be utilised.

The design was based on the concept of utilising the primary solids to retain the secondary solids. Given that this would be the first industrial waste disposal facility in New Zealand to incorporate this philosophy, the design included additional measures to confirm the feasibility of the operation and to allow the facility to be monitored during the initial landfilling phase of the complex.

The initial containment bund was constructed to a height of 5 metres, to enable initial filling of the secondary solids and allow the generation of a phreatic surface within the secondary solids to be monitored. This compacted earth bund provided an initial barrier and allowed the primary solids to be deposited in the area to develop a substantial bund with a crest width in excess of 50m. At this width, the stability for the worst case scenario of totally saturated secondary solids being retained and a phreatic surface developing within the primary solids bund, was considered acceptable.

The rate of rise of the secondary solids decreases as the available area within the deposition area increases. In order for the secondary solids to be contained, the containment wall above the initial earth bund is to be constructed from primary solids and will have to be constructed at a rate in excess of the rate of rise of the secondary solids. To ensure that the rate of rise of the primary solids is in excess of the secondary solids rate of rise, Phase 1 of the primary solids landfilling is limited to an area of approximately 5 ha or less. This provides the required rate of rise for the primary solids. Filling beyond this area (with the exception of the noise bund) will not commence until the containment bund has been constructed to full height of between 120-130mRL. This is illustrated in Figure 1.

As part of the consenting process a range of environmental effects were considered – groundwater, surface water, ecological, atmospheric, noise, archaeological, amenity, visual and nuisance (Pattle Delamore Partners, 2009). The assessment found that effects of the leachate from the primary and secondary solids on the groundwater were considered to be minor. However based on the groundwater model which indicated a "soft" groundwater divide between the valley site (draining to the wastewater treatment ponds) and the area to the north of the valley (draining to the Mangone Stream) a bund of compacted earth was designed to move any deposition of secondary solids to a min distance of 10m away from the divide.

The effects on the surface water and ecological environment were mitigated through the use of stormwater detention ponds at the end of the valley to control stormwater runoff and apply treatment to the stormwater prior to discharge to the downstream wetland. The effects on the other aspects were considered minor. The visual and amenity aspects were enhanced by the planting of a screening forest along the northern edge of the valley which will provide a visual screen between the neighbours, State Highway and site. An extensive monitoring programme was a condition of consent and this is in line with the conservative approach taken by the regulators (Matuschka, 2003) and in accordance with approaching the design in a conservative manner.

An important part of the design was to assess the system risk of the facility. The environmental risks were covered by the assessment of environmental effects as summarised above. The health and safety risk was assessed by applying the principles of Dam Safety to the facility. Because of the non-spadeable nature of the secondary solids at the time of tipping, landfilling of this waste has been conservatively designed around liquid containment, even though the waste eventually solidifies as it drains. To confirm this, a set of pneumatic piezometers were installed to monitor the potential rise and fall of the phreatic surface within the body of the secondary solids.

Under the Building (Dam Safety) Regulations of 2008, promulgated under the Building Act 2004, this initial containment and future primary solids bund can be considered a large dam as it impounds more than 20,000 m^3 of potential liquid or fluid and has a height in excess of 4m. As a result the landfill will need to be classified in terms of Tables 1 and 2 of the Regulations once the regulations are in force. However an initial review of these tables indicates that the secondary solids landfill would be classified as causing minimal damage and that the classification would be Low given that fatalities are highly unlikely (Department of Building and Housing, 2008). The New Zealand Society on Large Dams (NZSOLD) Dam Safety Guidelines (NZSOLD, 2000) also provides a classification as to the potential impact of the dam. The NZSOLD guidelines contain four categories of Potential Impact Categories (PIC) namely; very low, low, medium and high. Based on these PIC's the secondary solids landfill would be categorised as Low to Very Low given minimal damage that could occur and the fact that no fatalities are expected.

An assessment based on the factor of safety of the primary solids containment bund has been undertaken to determine the minimum crest width of this wall during construction. The area is considered to be seismically active within the Rotoitipaku Fault Zone, which trends SW-NE running through the area. Bay of Plenty Regional Council (BoPRC, 2014) records indicate that the expected earthquake return period for earthquakes (in the Bay of Plenty region) is as follows:

- For a magnitude 6 to 7 earthquake, 5 to 10 years
- For a magnitude 7 to 8 earthquake, 35 to 45 years
- For a magnitude 8+ earthquake, 150 to 180 years

Therefore, an earthquake of between magnitude 6 to 8 can be expected during the life of the landfill. A review of the largest earthquakes recorded in the Bay of Plenty area are:

- Edgecumbe – 2 March 1987 magnitude 6.5.
- Gisborne – 20 December 2007 magnitude 6.8

- East Cape - 6 February 1995 magnitude 7.0
- Hawkes Bay – 3 February 1931 magnitude 7.8, 13 February 1931 magnitude 7.3 and 23 February 1963 magnitude 7.5.

Peak ground accelerations measured for the Edgecumbe and Gisborne earthquakes were 0.26g and 0.28g respectively. These two earthquakes fall within the range estimated by BoPRC and therefore these peak ground acceleration measurements are considered to be representative of a possible seismic event within the landfill area during the life of operation of the landfill. A stability assessment was undertaken to assess the required dimensions of the secondary solids containment bund under earthquake conditions (taken as 0.3g), typical to the area. The stability assessment involved the calculation of the factor of safety of the containment bund, when constructed from primary solids, to a maximum height of 30 metres. In these stability assessments worst case scenarios were modelled with phreatic surfaces being developed in line with those experienced in tailings dam impoundments (van Zyl & Harr, 1977). Based on the stability assessment, the containment wall will require a minimum crest width of 10m at all times to maintain an acceptable factor of safety in excess of 1.3 under static conditions and around unity under seismic conditions. As noted above, a minimum crest width of 50 m will occur during construction.

5 CONSTRUCTION

The pre-deposition works were constructed in 2011 - 2012 and involved the construction of the Secondary solids deposition area, the groundwater divide, noise bund, initial containment bund, stormwater ponds and all haul roads. These works provided the necessary infrastructure for the deposition of primary and secondary solids. As the works were all within the Rotoiti ash soils erosion of the formed earthworks was an issue and this was solved by the immediate application of liquid soil and mulch to prevent erosion. Stormwater swales were armoured against erosion and numerous soakholes were constructed to dispose of stormwater. Construction of all components was completed in June 2012.

6 OPERATION

6.1 Primary Solids Staging

The deposition of the primary solids is initially part of the secondary solids containment bund (See Figure 2). The containment bund of primary solids will be constructed over a six and a half year period reaching a height varying between RL120m and RL130m to emulate the surrounding topography. The NVL is operated by a contractor engaged by CHH.

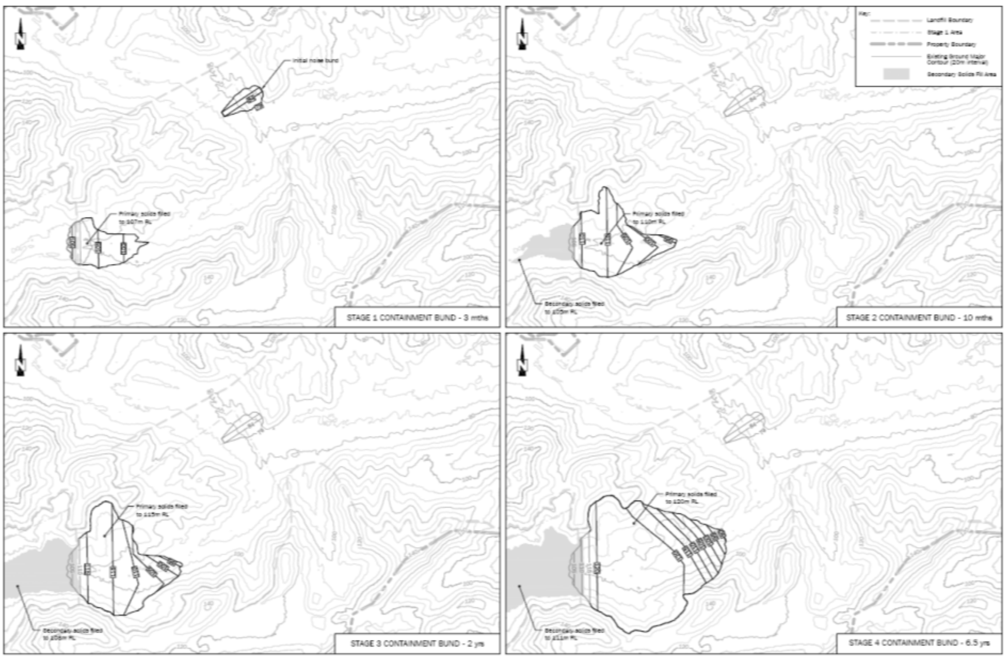

Figure 2. Proposed Containment Bund Filing

The primary solids are currently being compacted to form a stable bund (See Figure 2). Deposition of primary solids began in December 2012 and has been ongoing to-date. The solids are deposited by tip truck and spread and compacted by a bulldozer and excavator. The compaction is tested by means of scala penetrometer to ensure the required compaction is achieved. Six monthly site inspections and walkovers are undertaken by a suitably qualified person and regular monthly meetings are held between CHH and the Contractor.

Figure 3. Compacted Primary Solids

6.2 Secondary Solids Staging

The design has deposition of secondary solids behind the initial containment bund, which will allow for approximately one year of secondary solids deposition. Access roads were constructed around the perimeter of the secondary solids to allow even deposition from tip sites constructed along the road. The tip roads are accessed from the containment bund bench, and will allow secondary solids to be tipped around the entire perimeter of the secondary solids thus controlling the formation and position of any pool of supernatant water. The intention is to create a “beach” of secondary solids which directs the supernatant water to the back of the deposition area and away from the containment bund. The high permeability underlying soils will drain the secondary solids allowing the formation of an unsaturated body of a soil like material (See Figure 3)

Figure 4. Drained Secondary Solids

To date however, no secondary solids have been deposited and therefore no monitoring of the performance of the secondary solids has been able to be undertaken. Confirmation therefore of the visually observed behaviour of the secondary solids during the last deposition at the previous site has not been possible. Changes to the operation of the wastewater treatment plant indicate that minimal secondary solids will be generated in the near future.

6.3 Contingency

The major contingency events at the site are considered to be earthquakes and failure of the primary solids bund. In terms of construction the design of the underdrains and retaining structures, these have been designed to accommodate at least an earthquake loading of 0.3g with the underdrains also designed as flexible conduits by using drainage stone to ensure continuity along the drains.

The resource consent requires that an Embankment Safety Assurance Plan (ESAP) be developed for the facility. This was done and forms part of the monitoring plan. The key aspects of the ESAP are detailed below.

6.3.1 Embankment Safety Assurance Plan

6.3.1.1 Safety

The safety of the secondary solids containment bund could be threatened by climatic conditions, geotechnical instability, poor design, poor operational management, adverse environmental impacts or inadequate access controls. The containment bund is to be inspected and checked in accordance with a checklist provided in the monitoring plan. This inspection shall be done weekly for the duration of the deposition of secondary solids and for the month following cessation of deposition.

6.3.1.2 Stability

Stability of the containment bund is an aspect of safety that is considered important enough to be addressed separately. The major aspects which affect slope stability are:

- Slope angle.
- Strength of fill materials.
- Position of phreatic surface (saturation levels).
- Seismicity.

6.3.1.3 Emergency Situations

Three emergency situation categories for the facility have been established. These are:

Emergency Situation A – Evacuation

In this case the area downstream within the zone of influence shall be evacuated. The zone of influence covers the area of the valley between the primary solids landfill and the Booker wetland. Examples of such a situation are:

- Failure of the containment bund and secondary solids flowing downstream.
- Overtopping of the containment bund by secondary solids, supernatant water or stormwater.
- An earthquake or seismic event which has damaged the containment bund.
- Large cracks (exceeding 50mm in width) appear and continue to propagate in the containment bund. Cracks that increase in width at a rate exceeding 50mm per day are regarded as very serious.
- Relative vertical movement in excess of 500mm in the containment bund.
- Formation of erosion tunnels and/or seepage of more than 5L/sec on the outerslope of the containment bund and seepage that contains secondary solids.

Emergency Situation B – Preparedness

In this case the identified responsible people are notified and preparations are made to implement evacuation following investigation and/or discussion. Examples of such a situation are:

- Seepage on the downstream slope of the containment bund containing secondary solids.
- Supernatant water pool is adjacent to the containment bund and there is less than 1m of freeboard.
- Freeboard at any point is less than 500mm and there is free supernatant water on the surface of the secondary solids within 50m of the containment bund.

Emergency Situation C – Advice

In this case the operator notifies facility manager who then obtains professional advice. Examples of such a situation are:

- The presence of any seepage on the containment bund.
- Unusual increase in drainage flows from the underdrains especially during dry weather spells.
- Development of any wet patches on the downstream face of the containment bund
- Formation of erosion gullies in the containment bund
- Blocked underdrains
- Underdrains drawing fines from the secondary solids

- Presence of any cracking of the containment bund outer face or crest.

It should be noted that the above represent worst case scenarios and that these are not considered to represent expected or day to day operational conditions. Experience with the previous secondary solids deposition site indicates that any free water drains away and that the secondary solids effectivily drains to form an unsaturated soil like structure.

7 CONCLUSION

The design philosophy of using waste material to retain another type (or even the same type) of waste is common practice in the mining industry. The utilisation of this philosophy for the North Valley Landfill facility is a unique application for these types of waste products and this design has indicated that it can be successfully implemented.

The success of the implementation of this type of design depends in a good understanding of the nature and characteristics of the waste type involved. Adherence to sound engineering practice and assessing the risks also contribute to a successful design.

Unfortunately the lack of production of secondary solids to date has hampered the implementation of the design and the expected behaviour of the secondary solids has yet to be verified at the facility.

8 ACKNOWLEDGEMENTS

The authors would like to acknowledge Carter Holt Harvey Pulp & Paper Ltd for permission to publish this paper.

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