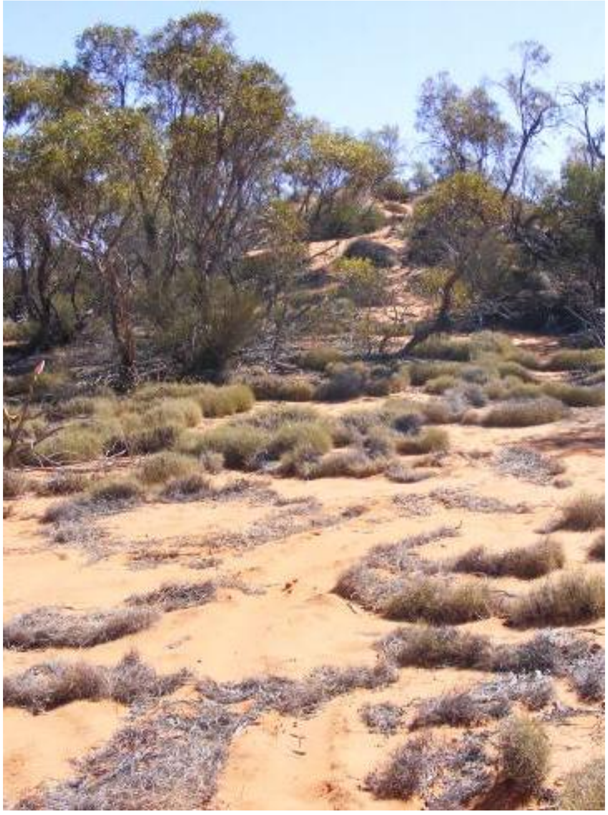

Landloch

Potential for runoff and erosion by water on waste landform batter slopes

Tropicana Gold Project

AngloGold Ashanti Ltd
and
Independence Group NL

July 2009

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To reference this report:
Landloch Pty Ltd (July 2009), *Potential for runoff and erosion by water on waste landfrom batter slopes.* Report prepared for AngloGold Ashanti Limited on behalf of the Tropicana Joint Venture

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Executive Summary

This report considers the potential for runoff and associated erosion to impact on the out-of-pit waste landforms planned for the Tropicana Gold Project.

The area shows little visual evidence of runoff from the existing dunes, which are stabilised by well established vegetation. Samples were taken from the site for particle size analysis, and show size distributions quite similar to Quaternary deposits of Aeolian sand in other areas of Australia.

Additional soil samples were taken from Tropicana and Havana areas for infiltration measurements, with samples from each site being effectively from dune and swale areas. The infiltration rates measured under simulated rain (44-140 mm/h) showed each dune material to have higher infiltration rate than its corresponding swale, which is consistent with other published data. The rates measured were quite consistent with data measured for similar soils in other studies. The infiltration data were used to derive effective hydraulic conductivity parameters, to enable long-term computer simulations of runoff and erosion from a test slope.

A synthetic 100-year climate file was developed for the Tropicana area, and the WEPP runoff/erosion model run to consider potential runoff and erosion from a 40 m high slope on 14 degree gradient. The simulations showed that runoff for the 100-year period simulated was zero or negligible if the soil on the slope had a steady infiltration rate of 30 mm/h or greater. At a steady infiltration rate of 15 mm/h, predicted average annual runoff was 10 mm/y and erosion was 8 t/ha/y. As three of the four samples tested had infiltration rates >70 mm/h, it can be concluded that the potential for significant runoff and runoff-induced erosion is extremely small.

Importantly, the runoff simulations indicate that landform design does not need to consider control of erosion. There would be value in considering compatibility of the planned landform with the local landforms and landscape, and a number of issues for soil placement and profile construction are discussed.

There may be potential for wind erosion to be significant, and a subsequent report will consider wind erosion potential and management.

1. Background

The proposed Tropicana Gold Project (TGP) is located 330km east north-east of Kalgoorlie on the western edge of the Great Victoria Desert (Figure 1). The TGP is a joint venture between AngloGold Ashanti Australia Limited (70%; manager) and Independence Group (30%) (Figure 1). The Great Victoria Desert landscape consists predominantly of Quaternary aeolian sand ridges interspersed with swale areas. The site is generally vegetated with a mixture of tree, shrub, and grass species. The sand dune areas are dominated by vegetation that provides surface contact cover.

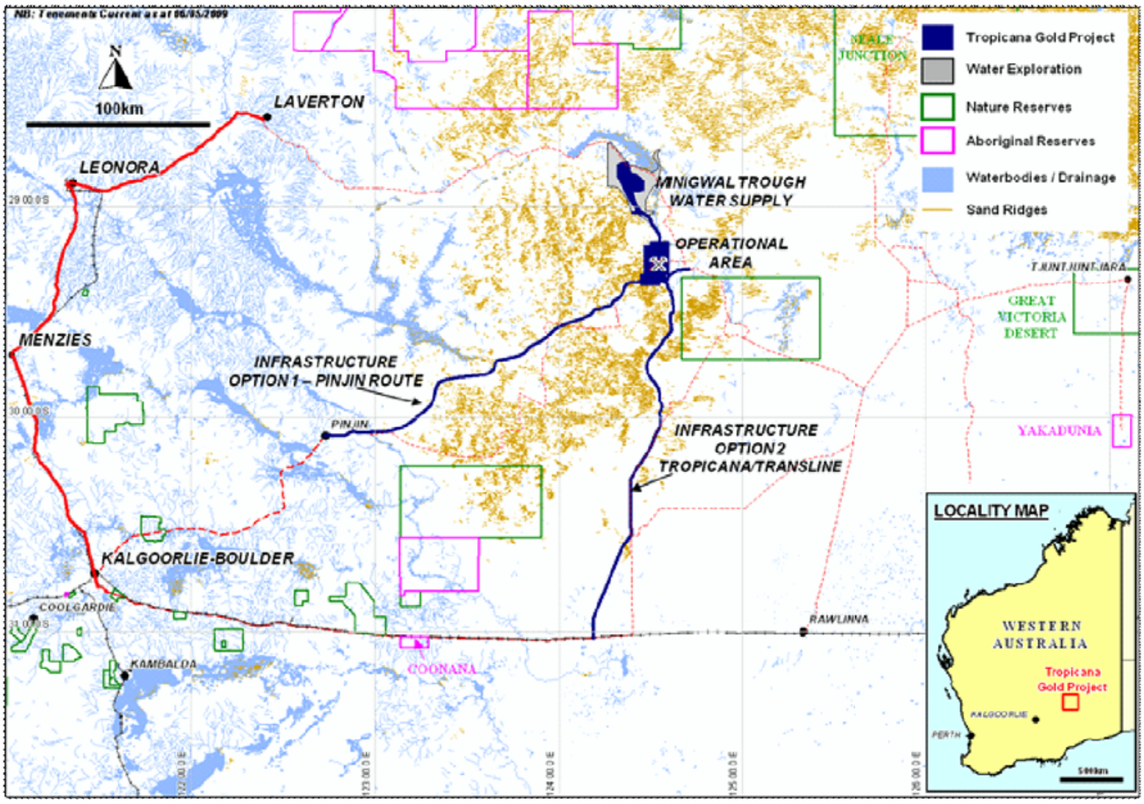


Figure 1*: Location of Tropicana Gold Project*

Drilling continued at the Tropicana prospect in 2007 with the mineralisation identified in the Tropicana-Havana zones moving into pre-feasibility study assessment in May. The study was focused on assessing the viability and options for developing an open-pit gold mining operation. An initial open-pit Mineral Resource (Inferred and Indicated) of 62.8Mt at 2.01g/t was announced in December 2007.

It is anticipated that the project will have a reasonably long life, and will generate a large out-of-pit waste dump that will be constructed progressively over the life of the mine.

Landloch Pty Ltd was engaged to consider a number of issues associated with the waste landform, including the need for design of the landform to ensure stability to erosion.

This report deals specifically with the risk of erosion by water.

2. Site inspection and sampling

Inspection of landforms in the proposed Resource Area during a visit by Dr Loch on 7-9 March 2008 found no visual evidence of runoff occurring on the dunes in the area, although it is clear that the area, as a whole, does produce runoff on occasions. The dunes are a loosely packed sand, whereas the swale areas are typically massive red earths (Figure 2).

Figure 2: *Swale profile (left), and view of lighter-coloured dune sand grading to red swale area (right).*

2.1 Initial sampling

Samples were taken of soil from surface and sub-surface horizons, and particle size distributions analysed (Table 1). Locations of sampling points (Figure 3) included one dune area (TPRC190D) and several swale sites.

Particle size analyses (Table 1) show typically high coarse sand contents (51-64%), very little silt, and generally low clay in the surface horizons. The data are consistent with material that has been transported by wind over moderate distances.

Table 1: *Particle size distributions of samples taken on the Tropicana site.*

Location	Depth (mm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)
TFRC 75	Surface[A]	13	3	44	39
TPRC 190 D	0 - 300	9	2	27	63
	600 - 900	19	1	29	52
TPRC 778	0 - 1000	4	3	32	64
TFRC 018	0 - 1000	9	2	34	57
TFRC 182	0 - 300	6	1	29	64
	900 - 1000	9	3	39	51

[A]: Site with calcrete rock mixed with surface soil.

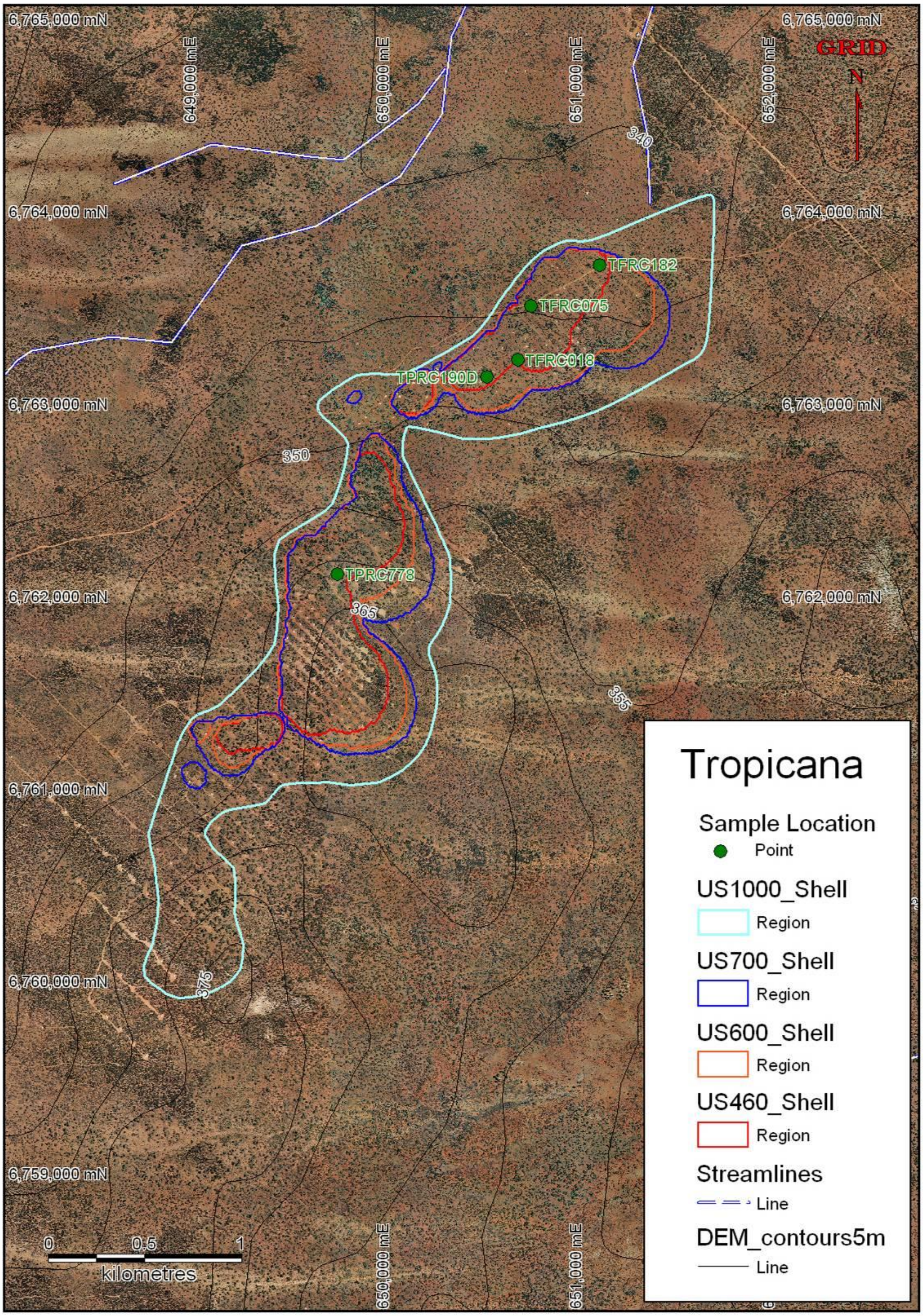


Figure 3: *Location of initial sampling points within the proposed Resource Area*

Data for similar soils were reported by Costantini and Loch (2002), who studied runoff and erosion under simulated rain on sandy loam soils developed on "extensive deposits of Quaternary wind blown sand" (Costantini *et al.* 1996) in a forestry setting in the coastal lowlands of south-east Queensland. Particle size distributions of the Quaternary sands studied by Costantini and Loch (Table 2) are quite similar to those of soils at the Tropicana lease (Table 1).

Table 2: *Particle size distributions of soils in the sites studied by Costantini et al. (1996) and Costantini and Loch (2002).*

Site	Sampling depth (mm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)
1 & 2	0-100	6	6	34.7	53.3
3	0-100	4	10	34.6	51.4
4	0-50	6	7	37.4	49.6
4	50-100	4	8	36	52
5	0-50	4	4	27.3	64.7
5	50-100	4	5	27.8	63.2
6	0-50	4	4	30.7	61.3

2.2 Sampling for infiltration measurements

An additional sampling was carried out to provide bulk samples for infiltration measurements. Four (4) samples were collected to 2 m depth, placed in 200 L drums, and transported to Landloch's laboratory for analysis. Sampling points are shown in Figure 4, with samples 1 and 2 taken from the Havana lease and samples 3 and 4 from the Tropicana lease.

From the sampling locations, it can be inferred that samples 1 and 3 are effectively dune material, with samples 2 and 4 being from swales.

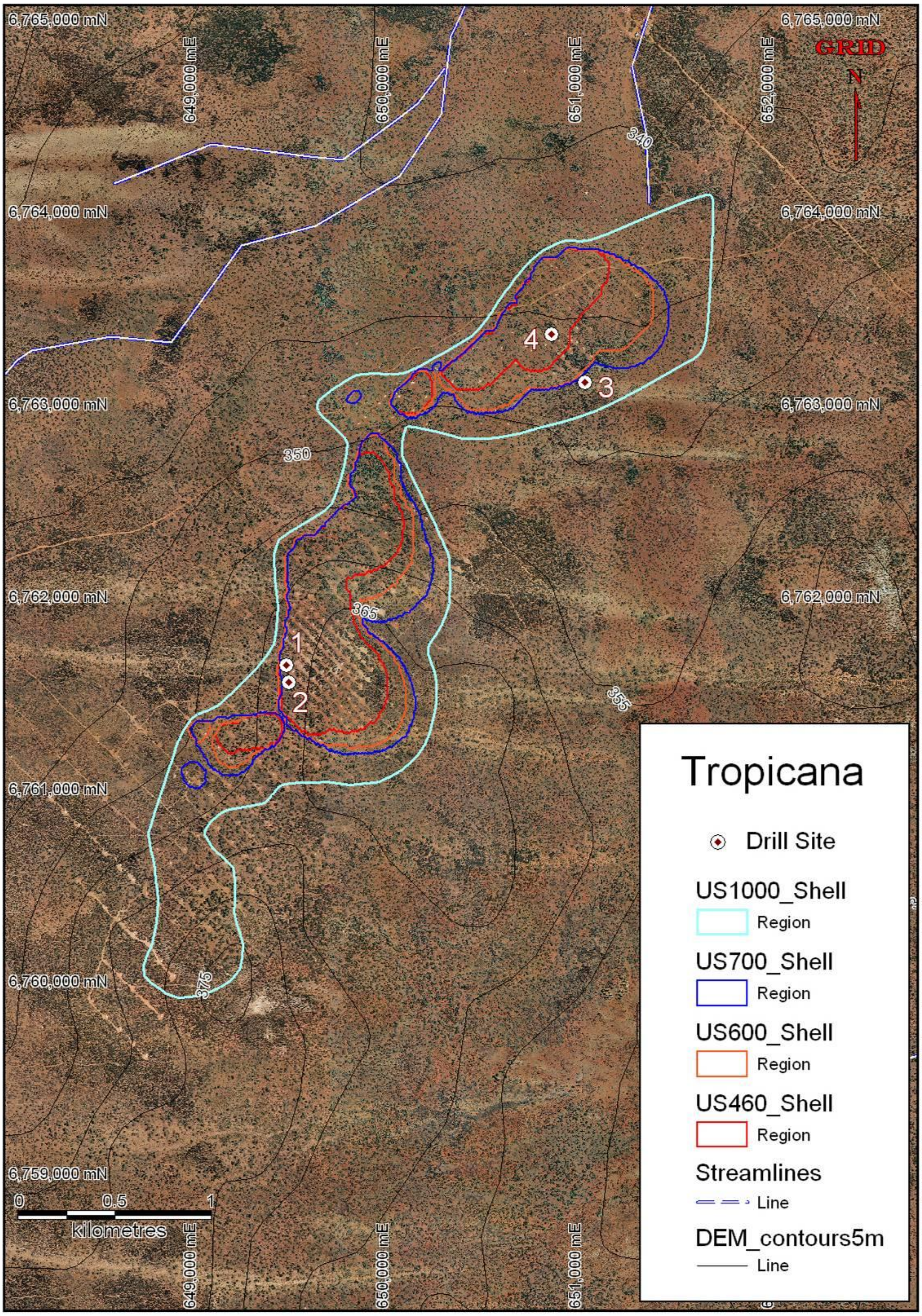


Figure 4: *Locations where samples were taken for infiltration measurements*

2.2.1 Infiltration measurements

For each sample, a single plot 750 X 750 mm and 200 mm deep was prepared and the sample lightly compacted during placement.

Simulated rain was applied to the plots, and measurements made of rainfall and runoff rates. The rainfall simulator was of the type described by Loch *et al.* (2001), and applied rain with drop kinetic energy consistent with natural rain at intensities ≥ 50 mm/h. Views of rain-impacted surfaces (after drying) are shown in Figure 5, and show some variation in the amount of very fine pebbles on the surface after rain.

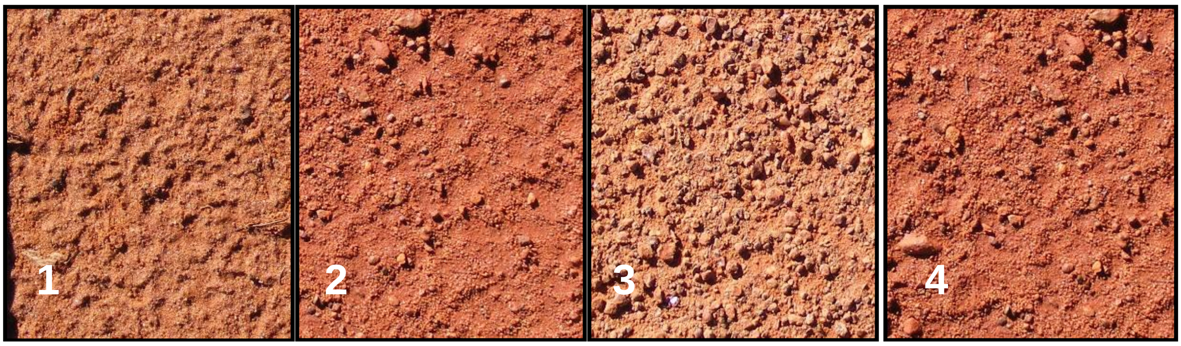


Figure 5: *Rain-impacted surfaces for samples 1-4. Height of each photo is equivalent to a distance of 100 mm on the plot surface.*

Initial and final water contents were taken into account (together with infiltration data) to derive effective hydraulic conductivities for the WEPP model (Table 3). The data show higher infiltration rates for the dune materials relative to associated swale samples. Infiltration was particularly high for sample 1 which was distinctively more sandy than the other three samples.

Table 3: *Measured infiltration rates and estimated hydraulic conductivities.*

Sample	Final infiltration rate (mm/h)	Effective hydraulic conductivity (mm/h)
1	141	115
2	71	45
3	77	50
4	44	25

2.2.2 Data from locations similar to TGP

The variation between dunes and swales is consistent with data from Greene *et al.* (1998), who studied runoff generation on a dune/swale area at Cobar in New South Wales. They found that undisturbed dunes produced no runoff at all when subjected to simulated rain at 30 mm/h, whereas the swale areas had 40-59% of the (approximately) 30 mm rain applied run off. Geomorphic age of the dunes in the Cobar area was estimated at 16,000-20,000 years.

Costantini and Loch (2002) studied runoff and erosion on Quaternary sand for forested sites that had all been logged, and then subjected to various degrees of disturbance, which – in most cases – included cross-slope mounding for planting of the next pine rotation. Simulated rain was applied to plots of 18 m^2 area, with rainfall application continuing until a steady runoff rate was reached. Infiltration rates were affected by water repellence in some instances (Costantini and Loch 2002), but final infiltration rates (drawn from unpublished data for the study) are as shown in Table 4).

Table 4: *Final infiltration rates measured on Quaternary sand by Costantini et el. (1996).*

Site	Landscape position and surface condition	Final Infiltration rate (mm/h)
1	Upslope, disturbed, 2% gradient furrow	55
2	Upslope, disturbed, 1% gradient furrow	63
3	Upslope, consolidated, 1% gradient furrow	32
4	Downslope, disturbed, 1% gradient furrow	88
5	Stickraked, 5% gradient	117
6	Undisturbed, 5% gradient	>125

In assessing the data in Table 4 (and from Dr Loch's memory of the experimentation), some comments are pertinent:

- Disturbance was a significant factor in reducing infiltration, by burying organic-rich material, and by destroying both surface cover and also root channels (macropores) that would otherwise contribute to infiltration;
- Consolidation (through time) would undoubtedly have been more effective under the higher rainfall of the coastal lowlands than it would be in an arid environment, as the degree of consolidation that occurs will depend on the duration of saturation of the surface.

Nonetheless, measured infiltration rates for the Tropicana/Havana samples are extremely consistent with the previous (field) measurements on similar materials using much larger plots shown in Table 4, giving considerable confidence that the measurements in Table 3 are a reasonable assessment of likely infiltration rates for a waste dump constructed of similar materials.

3. Simulations of runoff

The effective hydraulic conductivity values were used in simulations of runoff and erosion for a test slope 40 m high, on 14 degree (25%) gradient, with no vegetation cover. Soil depth was input as 1 metre. The WEPP (Water Erosion Prediction Program) model (Flanagan and Livingston 1995) developed by the US Department of Agriculture was used. The model was run for a synthetic 100-year climate file developed to describe rainfall at the Tropicana site. Greater detail on the WEPP model is given in Appendix 1 and information on preparation of the climate file is given in Appendix 2.

WEPP model output (Figure 6) shows that predicted runoff declines to negligible levels once steady infiltration rates exceed 30 mm/h. As infiltration rates measured for materials from the Tropicana and Havana leases were in the range 44 - 140 mm/h, it can be concluded that runoff and associated erosion by water is highly unlikely to be a significant issue for the planned Tropicana waste dump.

Even where infiltration rates were assumed to be much lower than the rates measured, predicted erosion rates were not large. For example, for a steady infiltration rate of 15 mm/h and annual runoff of 10 mm/y, predicted annual erosion on the batter slope tested averaged 8.3 t/ha/y. (Erosion prediction used default erodibility values for the sandy material considered.)

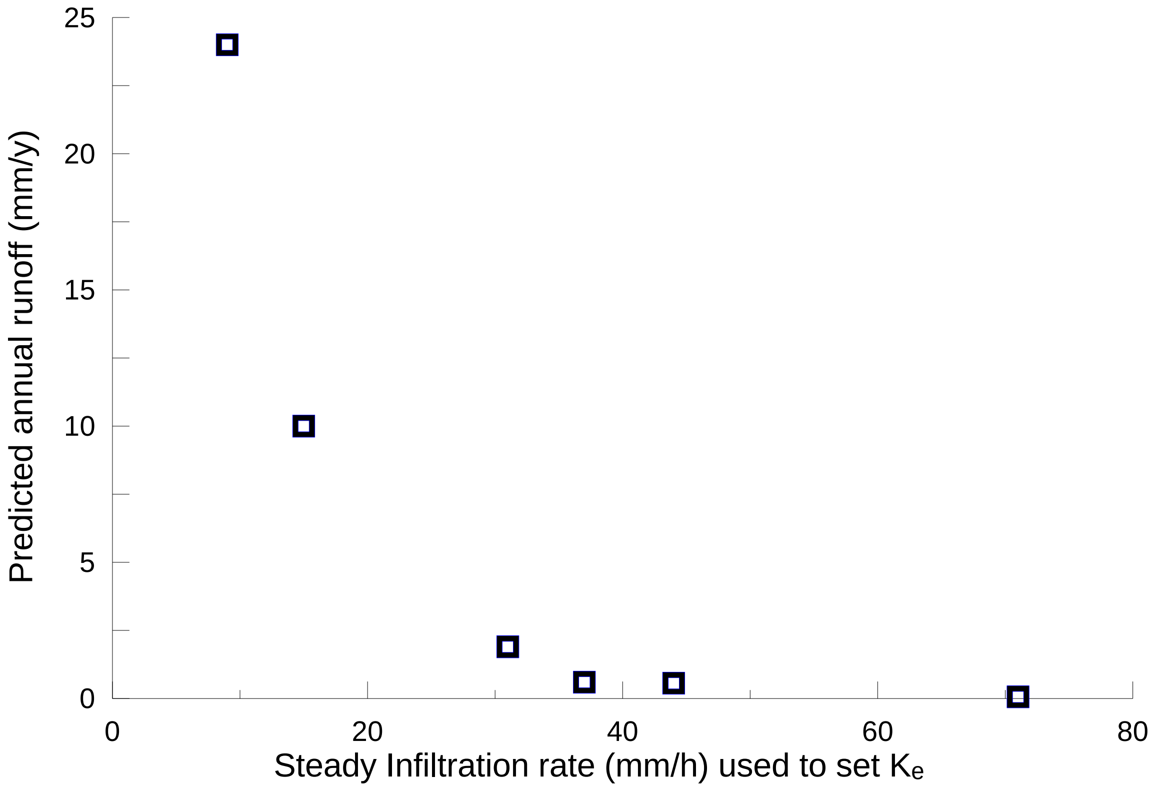


Figure 6: *Predicted impact of steady infiltration rate (described via changes in hydraulic conductivity, K_e) on predicted long-term annual average runoff from a 40 m high slope bare of vegetation.*

Nonetheless, to minimise risk as much as possible, it would be desirable to place material from dunes (with highest infiltration capacity):

(a) On the top of the waste landform to ensure that there is no runoff discharged from the top of the landform onto the batter slopes; and
(b) On the upper half of batter slopes to minimise development of runoff on the batters.

Swale material would be best placed on the bottom half of batter slopes and (if necessary) in a central zone on the landform top, provided there was at least a 30 m buffer of dune material between swale material and the outer batters.

4. Landform design priorities

4.1 Overview

The combination of low rainfall and high infiltration rates means that runoff (and erosion by runoff) is quite unlikely to occur on the waste landform that is likely to be constructed during Tropicana operations.

Therefore, outer batter gradients and landform height are unlikely to impact on the risk of erosion by water, though it would be desirable for landform design to consider:

(a) Potential for the constructed landform profile to be consistent with the surrounding landscape; and
(b) The extent to which the constructed landform may dominate local landforms.

It would be advisable for batter gradients to be constructed consistent with local dune profiles (or preferably slightly flatter) so that availability of rainfall for plant growth is consistent with natural conditions. Slopes significantly steeper than those present on natural landforms may restrict plant growth.

However, it is likely that measures to reduce potential for wind erosion may be of greater significance, and may have some influence on the landform design developed. Wind erosion will be considered in a separate report.

4.2 Material placement

There are likely to be definite advantages in selectively stripping, stockpiling, and placing dune material of high infiltration capacity on the upper sections of the outer batters of the waste dump for its rehabilitation, and on parts of the top of the landform closest to the outer batters. Selective stripping of topsoil and its associated seed bank will be particularly useful for subsequent rehabilitation works.

Placement of material from the inter-dune (swale) areas should be governed by the need to minimise potential for runoff generation and accumulation. This material, with slightly lower infiltration capacity than the dune sand, could be placed in the centre of the flat top of the waste dump with a fringing area of dune material closer to the outer batters to intercept and infiltrate any runoff prior to it being discharged onto outer batters. Again, selective stripping of the surface layers may enable the soil seed bank to contribute to revegetation.

Vegetative material (tree and shrub debris) that is removed prior to stripping of topsoil should be stockpiled for subsequent placement in areas of greatest wind erosion hazard.

Rehabilitation works at Murrin Murrin Nickel Operation between Leonora and Laverton have shown significant increases in vegetation establishment where tree debris has been spread, so there are likely to be similar benefits in vegetation establishment if tree debris could be spread on rehabilitated slopes at Tropicana.

In stockpiling tree and shrub debris, care may need to be taken to:

(a) minimise the potential for fires to reach and destroy the stockpiles, and
(b) ensure that the stockpiles (if ignited) do not pose a risk to other site infrastructure.

This may require such materials to be stored on areas that have largely been cleared of vegetation.

4.3 Profile depths and plant growth

Waste dumps are often constructed by placing a layer of topsoil over some depth of “growth medium” or else by simply placing topsoil over relatively benign waste.

Generally, soil productivity (for plant growth) is seen to be a function of nutrient store and water holding capacity.

However, water balance simulations for a similar arid, sandy site indicate that water holding capacity is unlikely to be an issue. With all rain infiltrating, the capacity of the soil to hold water will only be limiting if the soil overlies a hostile material such that water draining into the hostile material becomes unavailable to plants. In general, for soils and climate similar to the Tropicana site, Landloch’s data indicate that most root activity will occur in the surface metre of soil, and that wetting to depths below 0.5 m will be relatively uncommon. However, if some vegetation creates water harvesting or water-concentrating areas, then spatially variable infiltration may cause deeper wetting and it may be desirable for tree roots to be able to penetrate to depths of 1-3 m. Deeper root systems would also anchor larger trees against wind.

In terms of creation of a functional soil profile, one major consideration will be the properties of the waste likely to be placed in the waste landform. If the waste material is likely to be hostile to plant growth, then a growth medium (topsoil, subsoil) depth of at least 1 metre will be needed. If the wastes are relatively benign, then the depth of topsoil and subsoil may be able to be reduced.

Soils in the area appear to be relatively uniform with depth, and apart from stripping a surface “topsoil” layer, it may be possible to strip a quite deep layer (up to several metres deep probably, particularly within the dunes) of material to act as subsoil or growth medium. Further information on soil chemical properties would be useful in guiding these decisions.

Observations of tree growth in the Tropicana area indicate that roots of larger plants typically penetrate to depths well in excess of 1 m. This may well indicate areas of high intake associated with trees due to – for example – canopies intercepting rain and channelling it to the trunk, so that stemflow causes deeper wetting under the trees. For that reason, it would also be preferable if the waste underlying the soil profile that is formed was not hostile to plant growth.

Soil nutrient stores will be naturally low, given the arid climate, low biomass production and sandy soils. Nonetheless, some fertiliser addition in conjunction with rehabilitation seeding would assist in restoring biomass and soil nutrient stores that will inevitably be depleted by the processes of vegetation removal and soil stripping, stockpiling, and spreading.

5. References

Chaves, H. M. L., Nearing, M. A., 1991. Uncertainty analysis of the WEPP soil erosion model. *Transactions of the ASAE*, 34: 2437-2444.

Costantini, A., Loch, R.J., and Bourke, J.J. (1996). Erodibility and hydraulic characteristics of stick-raked and continuously high-mounded sites used for reforestation with *Pinus* plantations in the coastal lowlands of south-east Queensland. Report commissioned by Hyne and Sons and QDPI Forestry, Qld Forestry Research Institute, Gympie.

Costantini, A., and Loch, R.J. (2002). Effects of site preparation on runoff, erosion, and nutrient losses from *Pinus* plantations established on the coastal lowlands of south-east Queensland, Australia. *Australian Journal of Soil Research* 40: 1287-1302.

Flanagan, D. C., and Livingston, S. J. (1995). WEPP user summary. NSERL Report No 11, USDA-ARS-MWA.

Ghidey, F., and Alberts, E.E. (1996). Comparison of measured and WEPP predicted runoff and soil loss for Midwest claypan soil. *Trans. Am. Soc. of Agric. Engrs.,* 39: 1395-1402.

Greene, R.S.B., Nettleton, W.D., Chartres, C.J., Leys, J.F., and Cunningham, R.B. (1998). Runoff and micromorphological properties of a grazed haplargid, near Cobar, NSW, Australia. *Australian Journal of Soil Research* 36: 87-108.

Liu, B.Y., Nearing, M.A., Baffaut, C., and Ascough II, J.C., (1997). The WEPP watershed model: III. Comparisons to measured data from small watersheds: *Trans. Am. Soc. of Agric. Engrs.,* 40(4): 945-951.

Loch, R. J., Robotham, B. G., Zeller. L., Masterman, N., Orange, D. N., Bridge, B. J., Sheridan, G., and Bourke, J. J. (2001). A multi-purpose rainfall simulator for field infiltration and erosion studies. *Australian Journal of Soil Research* 39: 599-610.

Nearing, MA and Nicks, AD. (1998). Evaluation of the Water Erosion Prediction Project (WEPP) model for hillslopes: in *Modelling Soil Erosion by Water* (J Boardman and DT Favis-Mortlock, eds.), Springer-Verlag NATO-ASI Series I-55, Berlin: 45-56.

Nearing, M.A., Govers, G., and Norton, L.D. (1999). Variability in soil erosion data from replicated plots. *Soil Sci. Soc. Amer. J.* 63: 1829-1835.

Nearing, M. A., Dear-Ascough, L, Laflen, J. M. (1990). Sensitivity analysis of the WEPP Hillslope Erosion Model. *Transactions of the ASAE*, 33: 839-849.

Nicks, A. D., L. J. Lane, and G. A. Gander. (1995). Weather generator. Chapter 2 in *USDA–Water Erosion Prediction Project: Hillslope Profile and Watershed Model Documentation*. D. C. Flanagan and M. A. Nearing, eds. NSERL Report No. 10. West Lafayette, Ind.: USDA–ARS Nat. Soil Erosion Research Lab.

Tiwari, A.K., Risse, L.M., and Nearing, M.A. (2000) Evaluation of WEPP and its comparison with USLE and RUSLE. *Trans. Am. Soc. of Agric. Engrs. 43: 1129-1135.*

Wischmeier, W. H., and Smith, D. D. (1978). Predicting rainfall erosion losses - a guide to conservation planning. US Department of Agriculture. Agriculture Handbook No. 537. US Government Printing Office, Washington, DC.

Yu, B. (2002). Using CLIGEN to generate RUSLE climate inputs. *Transactions of the ASAE*, 48: 993-1001.

Yu,B. (2003). An assessment of uncalibrated CLIGEN in Australia. *Agricultural and Forest Meteorology*, 119: 131-148.

Yu, B., and Rosewell, C.R. (2001) Evaluation of WEPP for runoff and soil loss prediction at Gunnedah, NSW, Australia. *Australian Journal of Soil Research* 39: 1131-1145.

Zhang, X.C., M.A. Nearing, L.M. Risse, and K.C. McGregor. (1996). Evaluation of runoff and soil loss predictions using natural runoff plot data. *Trans. Am. Soc. Agric. Eng.*, 39(3): 855-863.

Appendix 1: The WEPP model

The Water Erosion Prediction Program (WEPP) was developed by the United States Department of Agriculture (USDA) to predict runoff, erosion, and deposition for hillslopes and watersheds. It is the product of continued USDA research and development of soil erosion models since the 1940's. As such, it is based on an enormous body of research data and modelling experience, and is widely regarded as the state of the art in erosion modelling at this time.

WEPP is a simulation model with a daily input time step, but internal calculations can use shorter time steps. For example, the climate file (for each day) includes information on:

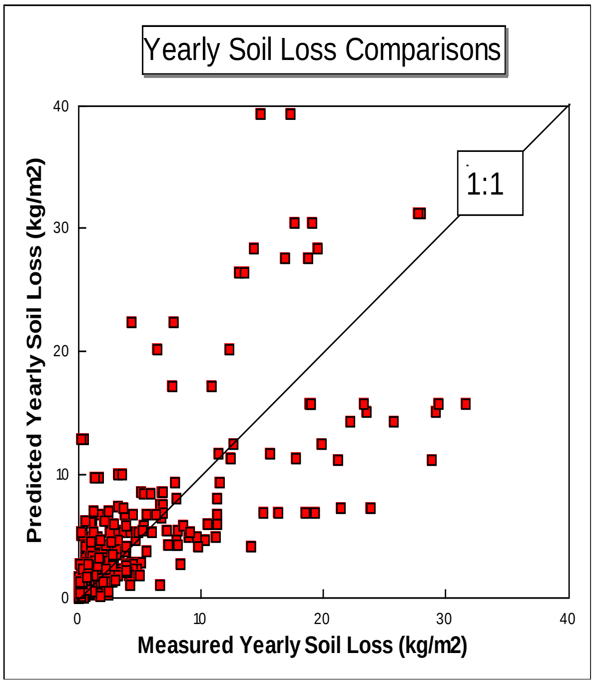
- Amount of rain
- Duration of the rain
- Time to peak intensity
- Ratio between peak intensity and average intensity.

This information is used in infiltration calculations, so that the model takes intensity and duration of rainfall into account. For every day, plant and soil characteristics important to erosion processes are updated. When rainfall occurs, those plant and soil characteristics are considered in determining whether runoff occurs. If runoff is predicted to occur, the model computes sediment detachment, transport, and deposition at points along the slope profile, and, depending on the version used, in channels and reservoirs.

Conceptually, the WEPP model can be divided into six components: climate generation, hydrology, plant growth, soils, management, and erosion.

The erosion component uses a steady-state sediment continuity equation as the basis for the erosion computations. Soil detachment in interrill areas is calculated as a function of the effective rainfall intensity and runoff rate. Soil detachment in rills is predicted to occur if the flow hydraulic shear stress is greater than critical shear and the flow sediment load is below transport capacity. Deposition in rills is computed when the sediment load is greater than the capacity of the flow to transport it.

The WEPP model has been widely tested against measured data (Nearing and Nicks 1998, Ghidey and Alberts 1996, Liu *et al*. 1997, Zhang *et al*. 1996, Tiwari *et al*. 2000, Yu and Rosewell 2001). In general, the tests indicate that the model performs well – given that no erosion model is expected to be extremely precise, and that experimental erosion data are somewhat variable (Nearing *et al*. 1999). Interestingly, the model is more accurate in its prediction of long-term averages than of erosion associated with individual years (Figure A1-1) – again, a consequence of the extreme variability of erosion from individual events.



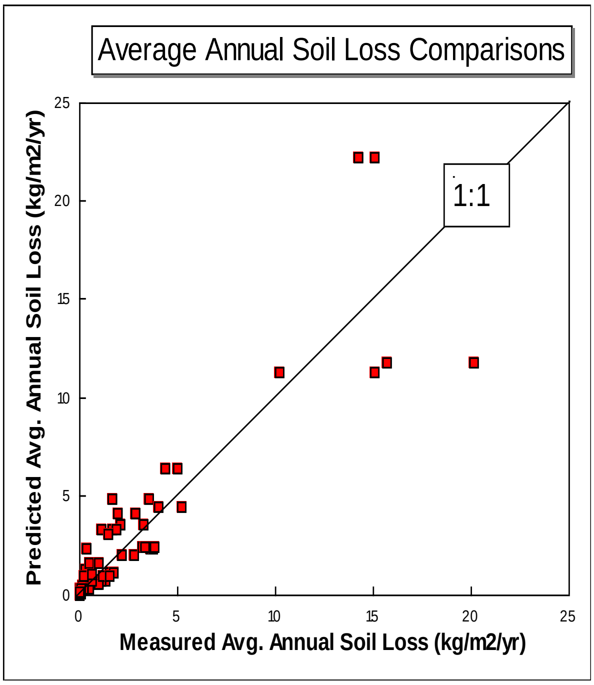


Figure A1-1: *Figures from Nearing and Nicks (1998) showing WEPP model performance against measured data.*

As the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) is calibrated to existing erosion data, its performance is effectively the benchmark for soil erosion model performance. Tiwari *et al*. (2000) found that WEPP performed as well or better than the USLE at 85% of sites. As the USLE parameters had undergone considerable refinement whereas the WEPP model was not calibrated at all, they considered that the WEPP model had performed quite successfully.

Various relationships within the WEPP model are based on considerable data and testing, with interpretations also being mindful of appropriate fundamental relationships and concepts. For example, recent unpublished experiments on steep slopes in China have shown that the model deals accurately with slope gradient in the range 9-58%, and with variations in slope length (Laflen, pers. comm.).

Appendix 2: Development of Tropicana climate file

For each day of simulation, WEPP requires ten daily weather variables:

- Precipitation (mm),
- Precipitation duration (hrs),
- Peak storm intensity,
- Time to storm peak,
- Average minimum temperature,
- Average maximum temperature,
- Dew point temperature,
- Solar radiation,
- Wind speed, and
- Wind direction.

Of these, the four precipitation-related variables (underlined in list above) are of particular importance because previous studies have shown that predicted runoff and soil loss are most sensitive to these precipitation variables (Nearing *et al*. 1990; Chaves and Nearing 1991).

For most sites around the world, complete historical weather data on these variables are not available. To use WEPP for runoff and erosion prediction, synthetic weather sequences that statistically preserve the mean and variations in the historical observations are required. CLIGEN is a stochastic weather generator that can be used to provide WEPP climate input files. CLIGEN has been extensively assessed for a wide range of climates in Australia, and it was found that CLIGEN was most suitable to provide the required climate input for WEPP to predict runoff and soil loss in Australia (Yu 2003).

This report briefly summarises how climate parameter values were prepared for CLIGEN to generate 100 years of daily data for the Tropicana site.

Data and method

The Tropicana site (124º33’20.80”E, 29º14’47.72”S) is located approximately 220 km ESE of Laverton (122º24’19.95”E; 28º37’33.24”S).

Data Drill data were sourced from the Bureau of Meteorology. The Data Drill accesses grids of data derived by interpolating the Bureau of Meteorology's observed station records. Interpolations are calculated by splining and kriging techniques. The data in the Data Drill are all synthetic; however the use of Data Drill data is appropriate in situations such as this where no observed data exist for the location.

Long-term (1889-present with an effective record length of 108.5 years) observed daily rainfall data are available for Laverton. Observed temperature data are available from the Laverton weather station (1957-1971) and the Leonora weather station (1957-2008). Solar radiation data are available through the Bureau of Meteorology (BOM) for the Tropicana site (1960-2008). BOM generate these data using a geostationary meteorological satellite (Yu 2003). These data are used as a check on the Data Drill data (see below).

Pluviograph (rainfall intensity) data are available from the BOM's Leonora weather station (121°19'38.39"E, 28º52'53.74"S), approximately 300 km west of Tropicana. This site contains data from February 1963 until June 2006, with an effective record length of 34.6 years (40.2 years of record at 86 % complete). Other pluviograph stations in the area contain very little data (less than 2 years) or contain highly segmented data. For example, the Kalgoorlie (121º28'20.29"E, 30º44'51".60S) pluviograph dataset contains data for only 67 % of the days between January 1939 and June 2006. The Leonora rainfall intensity dataset was used to generate the rainfall intensity parameters.

Using the data above, the following parameter values were computed and used for the Tropicana site:

- Mean daily precipitation on wet days for each month,
- Standard deviation and skewness coefficient of daily precipitation for each month,
- Probability of a wet day following a dry day for each month,
- Probability of a wet day following a wet day for each month,
- Mean daily max. temperature for each month,
- Standard deviation of daily max. temperature for each month,
- Mean daily min. temperature for each month,
- Standard deviation of daily min. temperature for each month,
- Mean maximum 30-min rainfall intensity for each month, and
- Probability distribution of the dimensionless time to peak storm intensity.

These parameter values for rainfall, temperature, and solar radiation were assembled to create a CLIGEN parameter file for the site.

A 100-year climate sequence was generated using CLIGEN version 5.1 (Yu 2002). The generated file is called Tropicana.cli, and was generated for the period from 1 Jan 2000 to 31 December 2099. A random seed of 000111000 was used for CLIGEN. This particular climate sequence can be reproduced with this specific random seed. Use of generated wind data has been switched off because no long-term wind data were available for the site, and Priestley-Taylor's method for estimating the potential evaporation will automatically be used by WEPP.

Data assessment

Comparison of Data Drill data and CLIGEN climate sequence

The long-term mean annual rainfall for the Laverton climate file is 197 mm (47.4 years of data from 1960 – 2008), and the simulated mean annual rainfall is 203 mm for the 100 year file created. The discrepancy is only 1.5 %. Figure 2-1 shows that mean monthly rainfall is also well preserved. The absolute error in observed and generated mean monthly rainfall was 1.1 mm. CLIGEN slightly over-predicts mean monthly rainfall for February, April, and July.

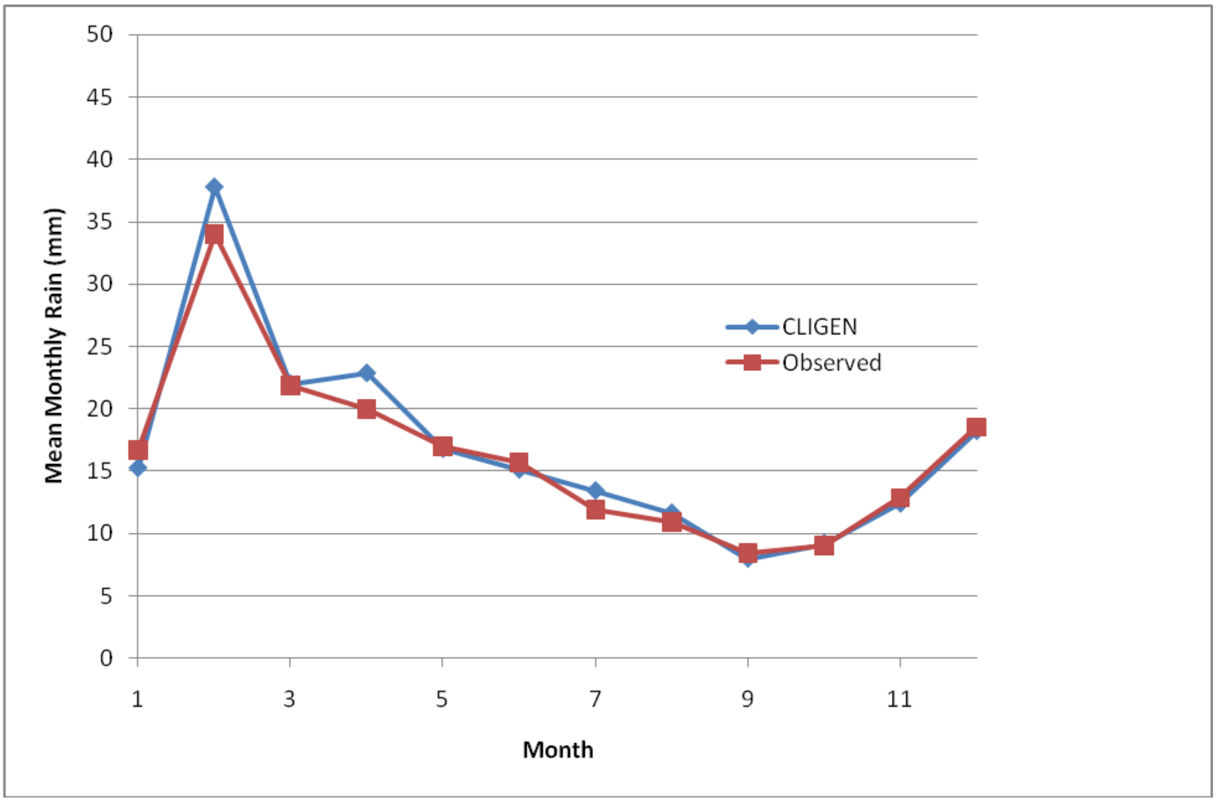


Figure 2-1: *Observed and CLIGEN simulated mean monthly rainfall for the Tropicana site.*

Extreme daily rainfall events were also compared. Figure 2-2 shows the annual daily rainfall compared with average recurrence interval (ARI). It can be seen that for this particular simulation run, the observed and simulated maximum daily rainfall totals match quite well, especially given the fact that rainfall at the site is highly variable. It shows that the extreme events in the CLIGEN dataset occur at the same frequency as observed and measured from climate data.

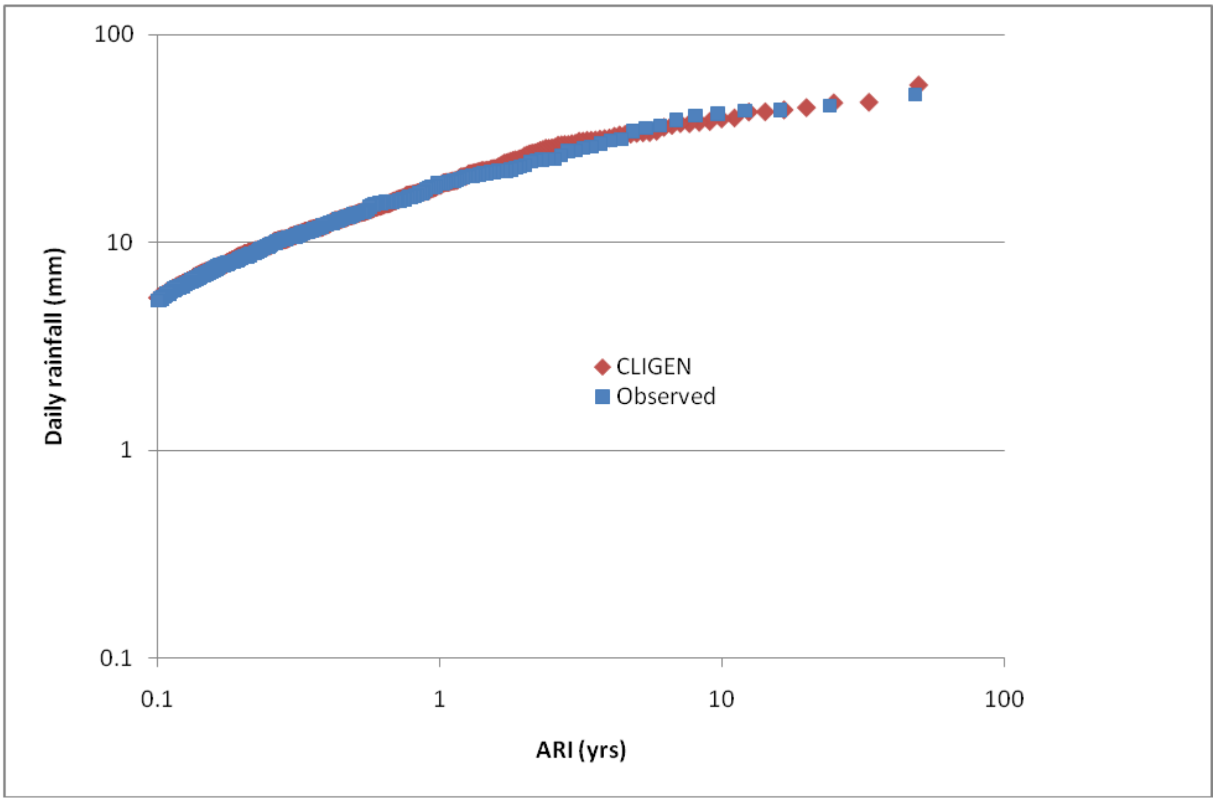


Figure 2-2: *Maximum daily rainfall amount versus average recurrence interval.*