APPENDIX E:

MEDLI MODELLING REPORT

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BMT WBM
Brisbane Office
Via Email

Attention: Nicole Ramilo

Dear Nicole

WASTEWATER MANAGEMENT MODELLING REPORT

1 Introduction

This wastewater management modelling report was prepared by BMT WBM's Newcastle Water and Environment Group to provide preliminary land requirements for the land application of treated effluent in the Caboolture identified growth area.

1.1 Aims and Objectives

The aim of the study is to identify the land area required for the land application of design wastewater loads for the Caboolture identified growth area.

The following objectives were identified for this study:

- Build numerical models that simulate the bio-physical processes governing water and nutrient dynamics within an effluent irrigation scheme.
- Identify the land area required for the land application of design wastewater loads for 10yr and 20yr planning horizons.
- Analyse and compare the three effluent irrigation concepts investigated.

2 Effluent Irrigation Concepts

Three wastewater servicing concepts were investigated:

1. Assuming dual reticulation and open space irrigation, with remainder disposed to land.
2. Assuming open space irrigation only, with remainder disposed to land.
3. Assuming no reuse, with total loads disposed to land.

The three servicing concepts investigated are summarised in Table 2-1.

Table 2-1 Wastewater Servicing Concepts

Concept / Option	Dual Reticulation	Open Space Irrigation	Land Application of Effluent
1	Yes	Yes	Yes
2	No	Yes	Yes
3	No	No	Yes

3 Model Development

Daily soil/plant water, nutrient and salt mass balance models have been constructed for each concept based predominantly on desktop data. Water, nutrient and salt modelling has been undertaken using *Model for Effluent Disposal using Land Irrigation* (MEDLI). MEDLI was selected due to its ability to meet the above objectives, industry familiarity and use of published, peer reviewed and largely validated algorithms.

3.1 MEDLI Model Description

MEDLI is a water and nutrient mass balance model developed by the Queensland Department of Natural Resources and Mines (now DERM) and the CRC for Waste Management and Pollution Control (Gardner and Davis, 1998). It is capable of simulating storage pond dynamics, irrigation scheduling, plant growth, transpiration and nutrient uptake, soil water and nutrient dynamics and salinity on a daily time step over long periods (up to 100 years). The structure of MEDLI is shown in Figure 3-1.

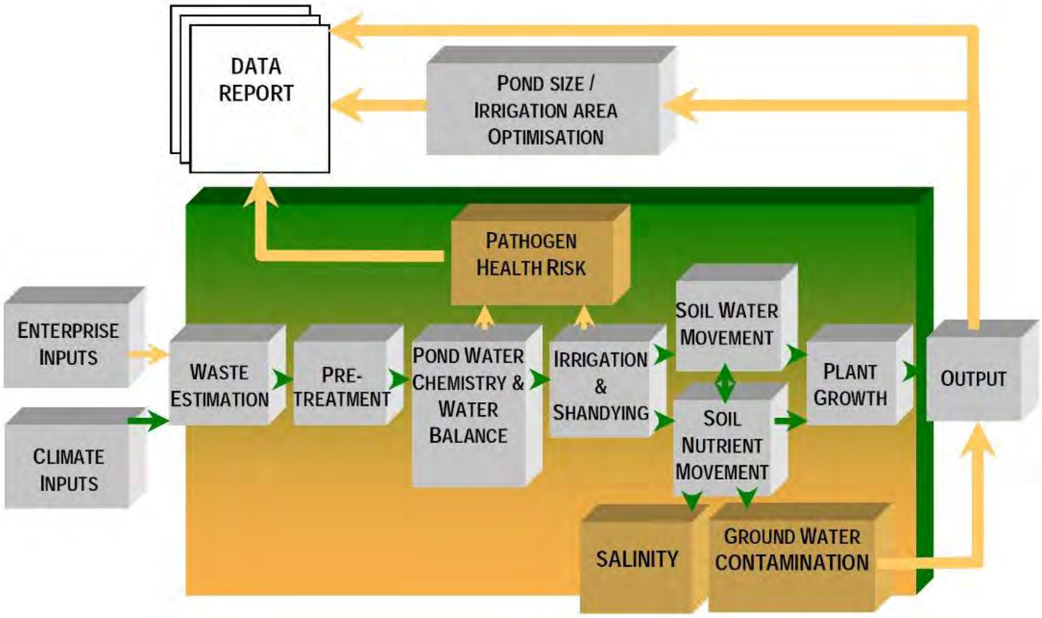

Figure 3-1 Structure of MEDLI (Source: Gardner and Davis, 1998)

MEDLI currently represents the most sophisticated and technically robust modelling tool for designing effluent irrigation schemes available in Australia and has been in the public domain for over ten years. The MEDLI Technical Manual (Gardner and Davis, 1998) provides a comprehensive description of the algorithms and modules which have been extensively peer reviewed and validated. Importantly, MEDLI is a process based mass balance model that includes dynamic, daily calculation of infiltration (rainfall and effluent), plant growth, transpiration, deep drainage, runoff and soil profile water. There is limited benefit in repeating small elements of the comprehensive Technical Manual (Gardner and Davis, 1998) here. Readers can obtain a copy of the software (or possibly at least the Technical Manual) from the Queensland Department of Environment and Resource Management (http://www2.dpi.qld.gov.au/environment/5721.html).

3.2 Design Parameters

3.2.1 Climate Data

MEDLI requires daily rainfall, evaporation, solar radiation, maximum and minimum temperature for the irrigation site. For this study interpolated data from SILO (DataDrill) were obtained in MEDLI format from Queensland DERM for the closest interpolated grid point (27.00 deg. S, 152.90 deg. E). The MEDLI modelling period was set at 60 years (1950 – 2010). The first year (1950) was used as a model warm up year to allow assumed existing organic-N to subside and grass growth cycles to stabilise. A summary of monthly climate statistics is provided below.

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CLIMATE INFORMATION
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Enterprise site: Caboolture                          -27.0 deg S  152.9 deg E
Weather station: caboolture_27.000S_152.900E (Int

  ANNUAL TOTALS    10 Percentile  50 percentile  90 Percentile
Rainfall mm/year        898.          1298.          1911.
Pan Evap mm/year       1484.          1591.          1681.

      MONTHLY        Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec  Year
Rainfall      (mm)   185  214  167  108  105   66   62   43   39   88  111  156 1345
Pan Evap      (mm)   181  145  140  111   86   71   80  104  134  162  175  189 1576
Ave Max Temp DegC     29   29   28   26   23   21   20   22   24   26   28   29   25
Ave Min Temp DegC     20   20   19   16   13   10    9    9   12   15   17   19   15
Rad    (MJ/m2/day)    22   20   19   16   14   12   14   17   20   22   23   23   18
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Figure 3-2 Summary Statistics for SILO MEDLI Climate Data

3.2.2 Soil and Landscape Characteristics

MEDLI requires details of the soil profile underlying the Land Application Area (LAA). To ensure adopted values were representative and based on best available information, a desktop site and soil assessment was undertaken using the following resources.

- Broad scale soil landscape mapping (DERM, 2011)
- MEDLI Technical Manual (Gardner and Davis 1998);
- Published data on typical Australian soils (Gardner and Davis 1998, Hazelton and Murphy 2007, ASNZS1547:2000); and
- Aerial photography.

Broad scale soil landscape mapping indicates that the Caboolture indentified growth area overlies two distinct soil landscapes, namely Ferrosols and Sodosols. Very little soil mapping or profile data was available to develop model parameters. As such, MEDLI soil parameters have been based on the typical characteristics of sodosols and ferrosols based on landform observed within the study area and previous soil investigations in similar soils undertaken by BMT WBM.

Ferrosols

Ferrosols are typically deep, strongly structured clay loams to clays that are high in free iron content giving them a red colour. They are highly suited to agriculture and the irrigation of effluent if left undisturbed. Ferrosols are moderately well drained, very high in phosphorus sorption capacity and typically greater than one metre deep. They are often derived from basic (volcanic) or basic metamorphic parent material in free draining landscapes such as plateaus and old alluvial levees. According to the broad scale soil mapping provided, ferrosols are likely to be restricted to the eastern end of the investigation area, closer to Caboolture.

Sodosols

Sodosols are relatively shallow, texture contrast soils (abrupt change in texture between A and B horizons) with sodic subsoils that are not strongly acid. Sodosols require careful management if they are to be cultivated or used for effluent irrigation due to their susceptibility to dispersion. They display limited development of soil structure, bleached A2 horizons and subsoils with very low permeability. Pollutant attenuation capacity is also typically limited. Sodosols are the dominant soil landscape within the Investigation Area. Their use for effluent irrigation will require detailed site and soil investigations, careful design and on-going management.

Relevant soil characteristics used for modelling are presented in Appendix A.

3.2.3 Vegetation Parameters

MEDLI offers five different cropping options to model plant growth and transpiration. For this assessment, it was preferable to adopt the mown pasture option. This cropping option is adopted for a species where the biomass is periodically mowed (cut) and removed from the irrigation site, allowing the pasture to regenerate from the residual biomass.

For this assessment vegetation parameters for a tropical pasture species were adopted.

Relevant vegetation parameters used for modelling are presented in Appendix A.

3.3 Wastewater Management System Data

3.3.1 Wastewater Flows and Loads

Expected wastewater loads for the Caboolture identified growth area were provided for the next twenty years. These wastewater loads are based on population growth for the region and growth in the commercial/industrial sector in the region as per Councils estimates. The annual wastewater loads used in modelling are presented in Table 3-1.

Table 3-1 Design Wastewater Loads used in MEDLI Modelling

Concept	Wastewater Load (ML/day)	
	10yr Planning Horizon	20yr Planning Horizon
1	0.76	2.34
2	1.63	5.12
3	3.21	10.35

Table 3-2 summarises the effluent quality adopted for this study which were supplied by the client based on the nearby Woodford STP which produces Class B effluent. Class B effluent was adopted based on the *Queensland Water Recycling Guidelines* (EPA, 2005).

Table 3-2 Design Effluent Quality used in MEDLI Modelling

Parameter	Design Value
Total Nitrogen	5 mg/L
Total Phosphorus	1 mg/L
Electrical conductivity	<1 dS/m
TDS	500 mg/L

3.3.2 Storage Configuration

Based on recommendations provided by Unitywater, a 110 day wet weather storage was adopted for the wastewater management system (i.e. storage capable of holding 110 days of the design wastewater load). The storage was modelled as a covered storage with zero evaporation from the storage and zero rainfall catchment. The storage was modelled as a covered storage due to the lack of information available for the configuration and location of the storage pond. Modelling the storage as covered effectively means that the volume of water entering the pond via rainfall is equal to the volume of water lost from the storage via seepage and evaporation. The wastewater management system was designed for zero overflow from the storage.

3.3.3 Irrigation Scheduling

Irrigation scheduling rules are a critical component of a MEDLI model as they determine how often irrigation can occur and how much effluent can be applied on any given day. MEDLI offers five functions within the irrigation module.

- Maximum and minimum daily limits for irrigation based on the hydraulic constraints of the irrigation system, receiving capacity of the site or other site specific issue.
- Three choices for a trigger for irrigation to occur on a given day (a percent of plant available water capacity, a nominated soil water deficit or a nominated frequency of irrigation).
- Three choices for determining the depth of application (mm beyond field capacity, a fixed depth or a percent of requirement to field capacity).
- Nomination of an enforced period of no irrigation following an irrigation event.
- Ability to supplement effluent with alternative water supplies (shandying).

Irrigation scheduling design parameters used in MEDLI modelling were developed in an iterative fashion through the modelling process. The parameters that were adjusted to develop an optimum design configuration including the irrigation trigger and depth of application. It should be noted that the irrigation parameters differ between soil landscapes due to differences in the hydraulic capacity between the two soil landscapes.

The irrigation scheduling design parameters used in MEDLI modelling were developed using the following steps:

1. Daily time series of soil water profile were analysed for days of soil saturation to determine the long term acceptance rate of the two soil landscapes modelled. The long term irrigation loading rate (equal to the long term acceptance rate of the soil) for the Ferrosol soil landscape was found to be 4mm/day and for the Sodosol soil landscape 2mm/day.
2. The minimum land application area (LAA) for each scenario and planning horizon was then calculated based on the long term irrigation loading rate for the two soil landscapes, and the daily wastewater load to be irrigated. The minimum LAA (hectares) is equal to the daily wastewater load (ML/day) divided by the long term irrigation loading rate (mm/day) multiplied by 100.
3. The depth of application (mm beyond field capacity) was then determined by calculating the minimum depth of application required to maintain the long term irrigation loading rate and limit overflow from the storage to zero. The minimum depth of application for the Ferrosol soil landscape was found to be 14mm/day and for the Sodosol soil landscape 12mm/day.

Relevant irrigation parameters used for modelling are presented in Appendix A.

4 MEDLI Model Results

A summary of the MEDLI results is provided in the following section.

Table 4-1 summarises the MEDLI results for the Ferrosol soil landscape.

Table 4-1 MEDLI Results – Ferrosol Soil Landscape

Scenario	Wastewater Load (ML/day)	Minimum LAA Required (ha)	Storage Retention Time (days)	Overflow (ML/yr)	Long Term Irrigation Loading Rate (mm/day)
10yr Planning Horizon					
1	0.99	25	110	0	4
2	1.63	40	110	0	4
3	3.21	80	110	0	4
20yr Planning Horizon					
1	2.34	60	110	0	4
2	5.12	130	110	0	4
3	10.35	260	110	0	4

Table 4-2 summarises the MEDLI results for the Sodosol soil landscape.

Table 4-2 MEDLI Results – Sodosol Soil Landscape

Scenario	Wastewater Load (ML/day)	Minimum LAA Required (ha)	Storage Retention Time (days)	Overflow (ML/yr)	Long Term Irrigation Loading Rate (mm/day)
10yr Planning Horizon					
1	0.99	50	110	0	2
2	1.63	80	110	0	2
3	3.21	160	110	0	2
20yr Planning Horizon					
1	2.34	120	110	0	2
2	5.12	260	110	0	2
3	10.35	520	110	0	2

5 Conclusions

The land area requirements presented in this report are based on a preliminary desktop appraisal of potential land application scenarios for Caboolture Investigation Area. Results for sodosols in particular are conservative given the potential for major constraints to effluent irrigation. It is recommended that more comprehensive site and soil investigations and modelling be undertaken to identify specific sites with potential for land application.

Yours Faithfully
BMT WBM Pty Ltd

Ben Asquith

Associate

6 References

Hazelton, P. and Murphy, B. (2007) Interpreting Soil Test Results: What do all the numbers mean? CSIRO Publishing.

Gardner, T. and Davis, R. (eds.) (1998) MEDLI Version 1.2 Technical Manual. Queensland Department of Natural Resources and Mines: Primary Industries and the CRC for Waste Management and Pollution Control.

Standards Australia (2000) AS/NZS1547:2000 On-site domestic wastewater management. Standards Australia.

APPENDIX A: MEDLI Input Parameters

Parameter	Unit	Ferrosol	Sodosol	Comments / Source
Enterprise - Effluent Characteristics				
Type		Other	Other	
EC	ds/m	0.78	0.78	
TDS (mg/L)	mg/L	500	500	
Effluent Volume per Working Day	ML	see N2162_Wastewater_Flows.xlsx	see N2162_Wastewater_Flows.xlsx	
Total Nitrogen	mg/L	5	5	Class B effluent.
Total Phosphorous	mg/L	1	1	
Enterprise - Irrigation				
Area	ha	N/A	N/A	Irrigation parameters developed in an iterative fashion through the modelling process. Refer to Section 3.3.3 of report.
Method		Centre Pivot	Centre Pivot	
Minimum	ML/ha/day	0.005	0.005	
Maximum	ML/ha/day	At full scheduled rate	At full scheduled rate	
Trigger		1mm Soil Water Deficit (SWD)	1mm Soil Water Deficit (SWD)	
Application		14mm beyond Drained Upper Limit	12mm beyond Drained Upper Limit	
Technical - Pond				
Hydraulic Retention Time	Days	110	110	Based on recommendations provided by Unitywater.
Max Length of Wetted Surface	m	Pond storage sized to 110 days hydraulic retention times - varies between scenarios (1,2 or 3) and planning horizons (10yr or 20yr)	Pond storage sized to 110 days hydraulic retention times - varies between scenarios (1,2 or 3) and planning horizons (10yr or 20yr)	
Max Width of Wetted Surface	m			
Max Water Depth	m			
Max Drawdown	m			
Freeboard	m			
Technical - Soil Water				
No. of Layers		4	2	Based on typical charcetristics of Sodosol and Ferrosol soil landscapes.
Soil Layer Thickness (Layer 1,2,3,4)	mm	100, 500, 600, 800	200, 1000	
Lower Strorage Limit (Layer 1,2,3,4)	%v/v	25.5, 27.9, 29, 29	18, 25	MEDLI Manual (Gardner & Davis, 1998)
Upper Storage Limit (Layer 1,2,3,4)	%v/v	41.2, 37.3, 39, 41.8	34, 42	MEDLI Manual (Gardner & Davis, 1998)
Saturated Water Content (Layer 1,2,3,4)	%v/v	46.6, 49.8, 50.6, 52.7	45.6, 49.3	MEDLI Manual (Gardner & Davis, 1998)
Saturated Hydraulic Conductivity (Layer 1,2,3,4)	mm/hr	50, 10, 10, 10	5, 1.2	MEDLI Manual (Gardner & Davis, 1998)

Parameter	Unit	Ferrosol	Sodosol	Source
Technical - Plant				
Option		Continous Pasture	Continous Pasture	MEDLI Defaults
Species		Tropical Pasture	Tropical Pasture	MEDLI Defaults
Max Crop Coefficient		0.8	0.8	MEDLI Defaults
Max Root Depth	mm	800	800	MEDLI Defaults
Harvest Trigger Yield	kg/ha	8000	8000	MEDLI Defaults
Technical - Irrigation				
Nitrate N	%	55	55	MEDLI Defaults
Ammonium N	%	15	15	MEDLI Defaults
Organic N	%	30	30	MEDLI Defaults
Ammonium Loss During Irrigation Application	%	20	20	MEDLI Defaults
Techncial - Soil Phosphorous				
Initial Soil Solution P (Layer 1,2,3,4)	mg/L	0.01, 0.005, 0.005, 0.005	0.01, 0.01	Based on MEDLI defaults for soils with moderate to hish phosphorus sorption capacity for Ferrosol and low phosphorus sorption capacity for Sodosol
Adsorption Coefficient (Layer 1,2,3,4)		153.9, 309, 309, 309	73, 73	
Adsorption Exponent (Layer 1,2,3,4)		0.33, 0.25, 0.25, 0.25	0.39, 0.39	
Desorption Exponent (Layer 1,2,3,4)		0.27, 0.13, 0.13, 0.13	0.25, 0.25	
Techncial - Soil Nitrogen				
Nitrate N	mg/kg	10	2.5	MEDLI Defaults
Organic N	mg/kg	500	800	MEDLI Defaults
Ammonification of Soil Organic N		0.00035	0.00035	MEDLI Defaults
Denitrification		0.1	0.1	MEDLI Defaults