CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Water Network (WN) Design

From case study 1.1 using published source and sink data (Prakash *et al.*, 2005a), result network from MILP model running by GAMS can identify a minimum freshwater flow rate usage and minimum wastewater discharge as same as literature techniques such as WCA and WCC. In addition, WN result from MILP have lower streams usage compared with litelature network by NNA method. From the same data of sink and source as case study 1.1, case study 1.1b shows a difference result WN because of difference cost data. The network try to have lower streams (freshwater stream + spliting stream + wastewater stream) by 11 streams to 10 streams because of high piping cost by increase freshwater flowrate and unused source. From case study 1.1c using water network model for several freshwater source, difference cost of freshwater by various sources gives a difference network of WN by the same data of sink and source. Optimal WN is generated where 20 ppm with 50 $/t of freshwater source is chosen by MILP model. From case study 1.2 and 1.3 using published source and sink data (Foo, 2008), difference data and adatpted data are also run by MILP model. The result of minimum freshwater and wastewater flowrate are optimally ensured by WCA and WCC. In case study 1.3, lower sinks concentration limit in data, optimal WN will require higher minimum freshwater flowrate.

5.2 Water Network with Treatment and Regeneration

Case study 2 using published retrofit WN data (Tan *et al.*, 2007), which are paper process, freshwater flowrate required in process can be reduced by retrofitting network that incoporated by add regeneration unit. The initial network require 1989.06 t/h of freshwater and generate 1680.3 t/h where the total annual cost is $4,138,829.23 per year. WN is developed without regeneration added, freshwater and wastewater are decreased to 848.12 t/h and 539.36 t/h analyzed by WCA and WCC techniques where the TAC is \$1,564,642.88 per year. Retrofiting shows a better result by regeneration concern in the proper investment. Water Network with Treatment and Regeneration model running by GAMS give a result network with optimal flowrate. By maximum regeneration flow rate, freshwater flowrate is reduced to 308.76 t/h with zero waste discharged where the TAC is \$752,720.32 per year Furthermore, retrofit network result by NLP model is optimal than literature result retrofit network (Tan *et al.*, 2007) that indicate the efficiency of optimized-based method that is exceeding than insight-based method.

5.3 Water Network Design with Several Treating Units

The presented calculation procedure is another method to solve MINLP problem, which is very complex model, of water network synthesis. The best solution are slightly improved by each step because of previous calculated variables are used as initial value for next calculation. Second calculation is the key step where the proper treatment unit is chosen to treat wastewater to a desire composition. Third calculation is for piping calculation for the last calculation. From case study 3.1, in the last calculation, some flowrates are adjusted to lower piping annual cost, resulting in generating economical water network. Otherwise, in case study 3.2, the fourth calculation does not active because of all possible streams piping cost are the same that no need a streams allocation by piping cost. This cascading calculation helps share the burden of solvers to reduce non-convexity of MINLP problem. The optimal water network result is close to one from literature (Sotelo-Pichardo et al., 2011) ensured that four-step calculation gives the optimal result.

5.4 Water-and-Heat-Exchanger Network (WHEN)

A new data of fixed-flowrate problem with temperature desired is developed initially consume 40.5 t/h of freswater, 3,543.75 kW and 4,147.50 kW of hot and cold utility with 10 exchangers where the TAC is \$2,343,023.16 per year. WHEN, developed MINLP model, can minimized both freshwater and utilities by both two methods of sequential step. From the same data, due to higher value of hot and cold utilities cost than freshwater cost, WHEN without WN design gives a better results than WHEN without HEN design. Furthermore, it gives a better result than two–step desgined WHEN because WN designed step of two–step design may decrease high energy source streams exist from five streams to three streams by non-isothermal mixing. However, this model is not the most economical result. Developed from two–step WHEN model, four–step WHEN model is designed by double the calculation procedure from two–step WHEN model that make the model has more opportunity to reach better optimal point. WHEN from four–step designed gives a best result compared with others by lowest TAC, which equal to $385,981.43 per year and total saving is $1,957,041.73 per year. The optimal network have a lower exchangers annual cost and freshwater annual cost even though the network consumes utility higher than WHEN without WN. Four–step calculation WHEN gives better results than one from two–step WHEN because of more degree of freedom of WHEN design in the model. Total heat exchangers area is decreased because of high temperature difference between sources and sinks ($TQUTH1_i$ and $TK2_j$) of HEN2. However, this model strategy can not guarantee that the result is global optimal result. The problem can be proved by other solvers to validate the result. Multi–step calculation WHEN might be considered in the future study to improve cost saving.