Executive Summary

The goal behind zero liquid discharge in a petroleum refinery refers to achieving a high enough purification of wastewater through treatment of contaminants so that water disposal is completely eliminated. By minimizing freshwater usage to that which is required only for start-up, petroleum refineries could cut freshwater consumption costs and promote a safer environment by disposing of fewer contaminants into sources of water. By modeling the contaminant outlet concentrations of the various regeneration processes, more realistic, detailed, and accurate results showed an optimal total annual cost of $950,000 associated with water using processes or a freshwater consumption of 31 tons/hour.

Mathematical models have been developed that optimize the way in which water streams run through a refinery. Currently, methods are being employed which model regeneration (i.e. water treatment) and water-using processes under the assumption of fixed outlet concentrations or a fixed process efficiency. These models output an optimal total annual cost of $1,220,000 and an optimal freshwater consumption of 34 tons/hour – both of which are slightly higher than the modeled outlet concentration numbers. In order to increase the accuracy in these older models, models of several common water-using processes and several water regeneration processes were developed which relate the outlet concentration of contaminants present in wastewater to parameters of the inlet stream and system parameters. The processes modeled included the API Separator, Chevron Waste Water Treatment, Reverse Osmosis, Activated Carbon Adsorption, and the Biological Treatment. The models were tested in GAMS to find optimal water flow stream placements and sizes between the refinery processes. An example of a model used in GAMS is given below:

- Chevron Wastewater Treatment (NH_3 Stripper, H_2S Stripper)
  - $$C_{out,NH_3}(ppm) = 0.9392\cdot[0.00068F^2 - 0.0065F - 0.057C_{in,NH_3} + 1546e^{-0.697N} + 0.00008069e^{0.025T} + 0.0613RFR - 4436000P^{-2.941} - 0.527\eta^2 - 0.752\eta + 7.105C_{in,H_2S}^{\ 0.47} + 0.238] + 4.1579$$
  - $$C_{out,H_2S}(ppm) = 0.0024e^{0.079C_{in,NH_3}} - e^{-0.039T} - 0.014\eta^{-0.138} + \left(1.011x10^{-4}\right)\cdot C_{in,H_2S}^{\ 2} - 0.0012\cdot C_{in,H_2S} + 21{,}700(Numberoftrays)^{-7.077} + 0.0158$$