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Phase 1: Assessment of Impact of Climate Change on River Water Quality and Ecology (TASK 3)

Your firm of consultants has been engaged to:

1. Update the existing Streeter-Phelps DO model of the 202.7 km reach of the Williams River of interest to take into account the extractions from the two additional irrigators, the discharges from the two new WWTPs and the inflow from the tributary. This will involve:
   - Changes to the specification of the existing S-P model.
   - Calibration of the k_a and k_d values for the additional reaches of the updated S-P model.
   - Validation of the updated S-P model.

   The expected design conditions are shown in Fig. 1. All WWTPs release water with an oxygen deficit DO_{sat}, and $CBOD_{ult}$=100 mg/L. It should be noted that all values of the re-aeration coefficient (k_a) and the decay coefficient (k_d) shown in Fig. 1 were obtained at 20 °C. Previous studies have indicated that the salinity in the main river is negligible and that the reach-averaged velocities can be predicted using the velocity-flow equation $u=0.027*Q^{0.72}$, where u is the velocity (m/s), and Q is the flow (m^3/s).

2. Develop a DO model for the tributary. As the tributary is very shallow, it results in dispersion in the direction of flow. In addition, it has a high nitrogenous biochemical oxygen demand. Consequently, use of a Streeter-Phelps model for modelling DO in the tributary is considered inappropriate. Consequently, you have been asked to develop an artificial neural network model for the tributary that is capable of predicting DO and BOD_{ult} at its confluence with the main river.

3. Evaluate the current status of the river, based on the minimum DO required for fish health.

4. Evaluate the status of the river in 2085, based on the minimum DO required for fish health. It is expected that due to population increases, the outflow from each water treatment plant along the river is expected to increase by a factor of 2. In addition, climate change is expected to increase temperatures and reduce streamflows.

All relevant data, software and project information are available in MyUni. All models / modelling tools that are not provided should be developed in MS Excel.

Submission

Please submit one hardcopy of the report per group in the submission box for EMMD outside of the School Office (N136).

The **assessment criteria** for the submission are as follows:

Goals/Grade	F < 50	P 50-64	C 65-74	D 75-84	HD >85
Specification of process-based DO model	Some major errors or omissions	Some minor errors or omissions	Well-specified with no errors or omissions	Well-specified with no errors or omissions, assumptions stated and discussed	
Specification of ANN DO model	Some major errors or omissions	Some minor errors or omissions	Well-specified with no errors or omissions	Well-specified with no errors or omissions, assumptions stated and discussed	
Calibration of process-based DO model	Some major errors or omissions	Use of single calibration method and/or minor errors or omissions	Correct use of gradient-based and evolutionary algorithm, limited parameter sensitivity analyses, limited comparison / discussion	Correct use of gradient-based and evolutionary algorithm, extensive parameter sensitivity analyses, limited comparison / discussion of methods and impact of parameters on algorithm behaviour	Innovative use of gradient-based and evolutionary algorithms, extensive parameter sensitivity analyses, critical in-depth comparison / discussion of methods and impact of parameters on algorithm behaviour
Calibration of ANN DO model	Some major errors or omissions	Use of single calibration method and/or minor errors or omissions	Correct use of gradient-based and evolutionary algorithm, limited parameter sensitivity analyses, limited comparison / discussion	Correct use of gradient-based and evolutionary algorithm, extensive parameter sensitivity analyses, limited comparison / discussion of methods and impact of parameters on algorithm behaviour	Innovative use of gradient-based and evolutionary algorithms, extensive parameter sensitivity analyses, critical in-depth comparison / discussion of methods and impact of parameters on algorithm behaviour
Validation of process-based DO model	Incorrect use of available data	Correct use of available data, use of single performance measure	Correct use of available data, use of multiple performance measures, limited discussion	Correct use of available data, use of multiple performance measures, in-depth, critical discussion of results	Innovative use of available data, use of multiple performance measures, in-depth, critical discussion of results, comparison with known physical attributes of system
Validation of ANN DO model	Incorrect use of available data	Correct use of available data, use of single performance measure	Correct use of available data, use of multiple performance measures, limited discussion	Correct use of available data, use of multiple performance measures, in-depth, critical discussion of results	Innovative use of available data, use of multiple performance measures, in-depth, critical discussion of results, comparison with known physical attributes of system
Extent of use of scenario analysis for decision - making	Inadequate scenario analysis	Consideration of basic scenarios, little discussion of results	Consideration of basic scenarios, in-depth, critical discussion of results	Consideration of a range of scenarios, in-depth, critical discussion of results	Consideration of an extensive, innovative range of scenarios, in-depth, critical discussion of results
Report ▪ Spelling and grammar ▪ Structure and organisation ▪ Completeness ▪ Clarity and readability	Inadequate	O.K.	Good		

Phase 2: Determination of Optimal Management Strategy in Response to Climate Change (TASK 5)

Your firm of consultants has been engaged to:

1. Develop optimal trade-off curves between the cost of management actions and DO levels in the river for the 2085 climate change scenario. The available management options include:
   - Changes in the treatment levels at the WWTPs. Currently, each WWTP uses primary treatment only, which produces a CBOD of 100 mg/L. There are also secondary and tertiary treatment options available at each WWTP. Secondary treatment will reduce the outlet CBOD to 60 mg/L, and tertiary treatment will reduce it to 40 mg/L.
   - A reduction in the water allocations made available to irrigators. Allocation levels considered include 5, 4, 3, 2, 1 and 0 m^3/s. The loss in revenue for the irrigators is expected to be \$20/ML reduction in water allocation.

   An optimal trade-off curve is to be obtained for each of the following scenarios:
   - Changes in WWTP treatment levels are the only available management options. No reductions in irrigator allocations are allowed.
   - Both changes in WWTP treatment levels and reductions in irrigator allocations are allowed and should be considered simultaneously.

   Design conditions from Fig. 1 should be used for the analysis, with flows and temperatures adjusted for the 2085 scenario. The upstream tributary design conditions are given in Table 1.

Table 1. Upstream Tributary Design Conditions

River Temp. (^oC)	Air Temp. (^oC)	Tributary Flow (m^3/s)	River Flow (m^3/s)	Salinity (uS/cm)	pH	UV Absorbance (@254 nm)	Turbidity (FNU)
13	18	9.71	17.5	394	6.91	117	83

2. Select 3 Pareto optimal solutions from the scenario that only allows changes in WWTP treatment levels and 3 Pareto optimal solutions from the scenario that allows changes in both WWTP treatment levels and reductions in irrigator allocations for further consideration. Rank these 6 solutions using the weighted sum MCDA approach in accordance with the following economic, social and environmental criteria:
   - Economic: Wastewater treatment costs
   - Environmental: Minimum DO levels in the river
   - Social: Reduction in irrigator profits

3. In order to enable robust decisions to be made, incorporate uncertainties in both the Performance Values and Criteria Weights into the weighted sum MCDA approach by using a Monte Carlo Simulation approach. Details of the uncertainties to be incorporated into the Performance Values are given in Table 2.

Table 2. Details of Random Variables

Parameter	Distribution Type	Distribution Values	
k_a	normal	μ=original value	σ=0.1 day^{-1}
k_d	normal	μ=original value	σ=0.05 day^{-1}
Tributary Flow	lognormal	μ=2085 value	σ=1.5 m^3/s
River Flow	lognormal	μ=2085 value	σ=3 m^3/s
Temperature	normal	μ=2085 value	σ=0.5 ^oC
Treatment Cost	normal	μ=original value	σ=\$20000
Irrigator Profit	uniform	min=\$10/ML	max=\$50/ML

4. Recommend a management action. Provide a detailed justification of your decision based on the results of your analyses.

All relevant data, software and project information are available in MyUni. All models / modelling tools that are not provided should be developed in MS Excel.

The **assessment criteria** for the submission are as follows:

Goals/Grade	F < 50	P 50-64	C 65-74	D 75-84	HD >85
Determination of Optimal Trade-Off Curves	Some major errors or omissions	Minor problems with use of evolutionary optimization algorithm and/or characterisation of Pareto front and/or consideration of scenarios	Correct use of evolutionary optimization algorithm, adequate characterisation of Pareto front, adequate consideration of scenarios, limited sensitivity analysis of parameters controlling evolutionary algorithm, limited discussion of results	Correct use of evolutionary optimization algorithm, adequate characterisation of Pareto front, adequate consideration of scenarios, limited sensitivity analysis of parameters controlling evolutionary algorithm, detailed, critical discussion of results obtained	Innovative use of evolutionary optimization algorithm, detailed characterization of Pareto front, innovative consideration of both scenarios, extensive sensitivity analysis of parameters controlling evolutionary algorithm, detailed, critical discussion of results obtained
MCDA	Some major errors or omissions	Minor problems with use of MCDA approach	Correct use of MCDA approach, limited discussion of results	Correct use of MCDA approach, detailed, critical discussion of results	
Consideration of Uncertainty in MCDA	Some major errors or omissions	Minor problems or omissions	Correct use of Monte Carlo procedure, correct characterisation and inclusion of uncertainties in both performance values and criteria weights, limited discussion of results	Correct use of Monte Carlo procedure, correct characterisation and inclusion of uncertainties in both performance values and criteria weights, adequate discussion of results	Innovative use of Monte Carlo procedure, correct characterisation and inclusion of uncertainties in both performance values and criteria weights, extensive critical analysis and discussion of results
Decision-Making Process	Choice of preferred management alternative given, no justification based on results obtained	Choice of preferred management alternative given, limited justification based on results obtained	Choice of preferred management alternative given, adequate justification based on results obtained	Choice of preferred management alternative given, detailed justification based on results obtained	Choice of preferred management alternative given, detailed justification based on results obtained, detailed discussion of assumptions and limitations
Report ▪ Spelling and grammar ▪ Structure and organisation ▪ Completeness ▪ Clarity and readability	Inadequate	O.K.	Good		

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