AGRICULTURAL NON-POINT SOURCE POLLUTION MODELING IN SG. BERTAM, CAMERON HIGHLANDS USING QUAL2E

(Permodelan Punca Pencemaran Tidak Tetap dari Aktiviti Pertanian di Sg. Bertam, Cameron Highlands Menggunakan QUAL2E)

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Abstract

QUAL2E is a widely used and accepted model in Malaysia in relation to impact assessments, discharge permit allocations and river rehabilitation studies. The use of the model for point-source evaluation is relatively straightforward, as the model has the in-built provisions for these types of applications. Non-point source pollution (NPSP) modeling using QUAL2E however requires the integration of hydraulic and hydrological principles not apparent to the model. The objective of this study was to identify sources of pollution along Bertam River sub-catchment related to a proposed agricultural development and its impacts towards ambient water quality from surface runoff with primary organic contribution from the fertilizers used. The Event Mean Concentration (EMC) was derived from typical land use classifications coherent to the specific area, whereas the runoff volume was calculated from precipitation using the Rational Equation. The model was then calibrated based on data collected on-site during high-flow conditions. Water quality constituents that came under close scrutiny for the modeling included; Biochemical Oxygen Demand (BOD₅), Total Suspended Solids (TSS), Ammoniacal Nitrogen (AN), Nitrate (NO₃⁻) and Phosphorous (P). The construction phase of the proposed agricultural development could result in immense deterioration of the ambient water quality of up to 2,000 mg/l for TSS (current is between 300 – 600 mg/l), on the downstream reaches if specific control measures are not met under high flow conditions. Construction of silt traps with at least 70% removal efficiency (1,500 mg/l) would result in a significant reduction of the TSS runoff quality to between 600 – 900 mg/l. For phosphorous, the ambient levels remained relatively high, even under high flow conditions as 5 mg/l downstream, though comparative to the low-flow conditions, some dilution was seen. The improvement between current and predicted ambient concentration at different phases of the development however was marginal (<15%).

Keywords: Bertam river, non point source pollution and QUAL2E

Abstrak

QUAL2E adalah model kualiti air yang digunakan di Malaysia untuk pelbagai aplikasi termasuklah dalam penilaian impak kajian alam sekitar, penentuan had maksima pelepasan efluen dan juga dalam kajian pemuliharaan sungai. Penggunaan model ini dalam penilaian kesan Punca Pencemaran Tetap dapat dilakukan secara langsung kerana ia mempunyai ciri-ciri sedia ada untuk tujuan tersebut. Walaubagaimanapun, Permodelan Punca Tidak Tetap menggunakan QUAL2E memerlukan integrasi prinsip-prinsip hidraulik dan hidrologi yang tidak sejajar dengan ciri yang sedia ada. Objektif kajian ini adalah untuk mengenalpasti punca-punca Pencemaran Tidak Tetap di dalam lembangan Sg. Bertam yang berkaitan dengan aktiviti pertanian dan impaknya terhadap kualiti air sungai akibat daripada sumberan punca organik (terutamanya baja) yang dibawa oleh air larian menggunakan QUAL2E. Keputusan Purata Punca Tidak Tetap (EMC) dikenalpasti berdasarkan penggunaan tanah sekeliling, manakala isipadu air larian ditentukan mengguna Formula Rational. Kalibrasi model kemudian dipastikan dilakukan menggunakan data kualiti air yang di ukur pada ketika kadar alir sungai berada pada paras yang tinggi. Permodelan kualiti air melibatkan parameter-parameter tertentu, termasuklah Keperluan Oksigen Biokimia (BOD₅), Pepejal Terampai (TSS), Ammonia Nitrogen (AN), Nitrat (NO₃⁻) dan Fosforus (P). Keputusan permodelan menunjukkan fasa pembangunan kawasan pertanian akan menyebabkan degradasi kualiti air yang teruk khasnya dari segi kandungan Pepejal Terampai, mencecah 2,000 mg/l (keadaan sekarang antara 300 – 600 mg/l), sekinira di tiada langkah kawalan dilaksanakan, akibat dari aktiviti pengosongan tapak. Penyediaan perangkap lumpur dengan kecekapan sekarang kurangnya 70% (1,500 mg/l) boleh memperbaiki keadaan, dengan mengurangkan kepekatan Pepejal Terampai dalam sungai antara 600 – 900 mg/l. Bagi Fosforus tidak banyak perubahan yang berlaku, di mana kepekatan bahan tersebut dalam sungai kekal pada paras 5 mg/l. Perbezaan kepekatan antara fasa berbeza pembangunan tanah juga didapati tidak banyak (<15%).

Kata kunci : Sg. Bertam, QUAL2E, Pencemaran Punca Tidak Tetap, Pertanian
Introduction

The proposed agricultural development shall cater for the growth and production of various vegetables and fruits, indigenous to cold climate conditions such as Bertam Valley. The primary receiving water body will be Sg. Bertam via its three (3) unnamed tributaries, which in this study were referred to as Stream A, B, and C (from upstream to downstream). The effect of the proposed agricultural development on water quality shall be in the form of runoff (during rain) with primary organic contribution from the fertilizers used. This is the main impact during the operational phase of the project. However it is also necessary to simulate the impact on water quality during the construction phase of the project, particularly the amount of Total Suspended Solids (TSS) which may significantly increase due to earth-works. Implicitly, this is to say that the most relevant deterioration may most likely be seen during high-flow conditions within the basin. In addition, an administrative building located within the proposed project site will host a conventional septic tank treatment system. It was thus also necessary to evaluate potential impact(s) from this source.

Located about 60 km from the proposed site, is a water treatment plant, catering for residents within the Bertam Valley area. Thus it is quite imperative that the current ambient water quality of Sg. Bertam be sustained to ensure a safe and hazard free drinking water source, even more critically so during high-flow periods (agricultural runoff) as well as during conventional flow as a result of the septic tank effluent discharge. Data from the JPS weather station in Cameron Highlands (from year 1992 – 1996) revealed that rainfall is highest towards the end of year (October to December) and towards the end of the first quarter (March and April) as shown in Figure 1.

![Figure 1: Rainfall Distribution Pattern at JPS Cameron Highlands Weather Station (1992 – 1996)](image_url)

Methodology

Prior to the model development, hydro-geometry and baseline water quality surveys at the prescribed sites were conducted throughout the Sg. Bertam watershed (refer <Figure 4.11 – 4.17 – your reference>). This exercise was necessary to ensure that the model could be calibrated as accurately as possible. Generally Sg. Bertam exhibited fairly good water quality during normal flow periods, between Class I and II of the Interim National Water Quality Standards (INWQS). This however changed during rainfall events where, single class deteriorations were observed at all of baseline stations. TSS is contributory towards the degradation, however, increment in other pollutant species such as the Chemical Oxygen Demand (COD), Ammonia Nitrogen (AN), Nitrate and Phosphorous were also progressive. This was indicative of the pollution event occurring as a result of the use of fertilizers at the existing plantations. Interestingly enough, no increase in pesticides and herbicides levels (as tested in accordance with the INWQS) was seen, where all samples depicted Non-Detectable (ND) levels for all of the parameters tested.
This however is rather anomalous considering the agricultural activities within the vicinity. The QUAL2E reach layout system and location of the sampling sites are shown in Figure 2. Water quality constituents that came under close scrutiny for the modeling include; Biochemical Oxygen Demand (BOD₅), Total Suspended Solids (TSS), Ammoniacal Nitrogen (AN), Nitrate (NO₃⁻), Phosphorous (P) and *Escherichia coli* (*E. coli*). Agricultural runoff and sewage impact are generally related to these parameters. Since runoff data of the site was not readily available, the Event Mean Concentration (EMC) by land-use classification adopted by Baird and Jennings (1996) [1] was used as an initial guess for the calibration proceedings as shown in Table 1. The model was then further calibrated based on in-stream field data collected to further refine its validity. Some deviation was observed between the literature and field values, where generally the agricultural constituents from the project site (based on the model calibration) seemed to be higher. This was not surprising, considering the extent of agricultural exploration within the project site as well as its surroundings and the influence of heavy tropical downpour and steep slope.

![Figure 2. QUAL2E Sg. Bertam Reach Layout](image)

Table 1: Event Mean Concentration (EMC) by Agricultural land-use [1]

<table>
<thead>
<tr>
<th>Constituent</th>
<th>EMC (mg/l)</th>
<th>Runoff Concentration (from model calibration, mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD₅</td>
<td>4</td>
<td>4.5</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen (for AN)</td>
<td>1.7</td>
<td>0.03 (AN as N)</td>
</tr>
<tr>
<td>Nitrate + Nitrite</td>
<td>1.6</td>
<td>6.9 (NO₃⁻ as N)</td>
</tr>
<tr>
<td>Total Phosphorous</td>
<td>1.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>107</td>
<td>498</td>
</tr>
</tbody>
</table>
For TSS EMC during the construction phase, the uncontrolled construction site runoff value of between 2,000 - 4,200 mg/l from literature was used [2]. The modeling exercise was then carried out on a worst case scenario basis to ensure maximum pollution control is practiced throughout the construction and operational phase of the project. The prescribed scenarios were as follows;

**Operational Phase (Conventional Flow) – Sewage Impact**

*Environmental Quality Act 1974, Standard B* formed the basis of the modeling scenarios. The modeling exercise shall therefore test this hypothesis to see whether it is sufficient for the case of Sg. Bertam;

a) **Effluent Standard B (Ammoniacal Nitrogen = 20 mg/l, Nitrate = 20 mg/l and Phosphorous = 20 mg/l, peak discharge flowrate = 0.003 m$^3$/s) compliance at measured flow conditions.**

b) **Raw effluent discharge [3] (BOD$_5$ = 250 mg/l, TSS = 300 mg/l, Ammoniacal Nitrogen = 50 mg/l, Nitrate = 50 mg/l and Phosphorous = 50 mg/l)**

c) **Shock loading due to sudden high volumetric discharge (Raw effluent discharge, burst discharge flowrate = 0.030 m$^3$/s)**

d) **E. coli** was modeled to enable estimation of an appropriate discharge quality relative to the current ambient population [4]. The effluent discharge rate was determined on a worst-case-scenario basis with an operating PE of about 1000 workers on-site (worst-case-scenario) and 225 liters/day/PE$^1$.

- Untreated Sewage : 50,000 cfu/100 ml
- Treated Sewage : 10,000 cfu/100 ml

**Construction and Operational phase (High Flow)**

i. **Current high flow condition ;**

ii. **Impact from agricultural runoff, concurrent with development (from Year 2008 – Year 2011) for BOD$_5$, TSS, AN, NO$_3$- and P.**

An extensive overland flow gauging and analysis would have been preferable to quantify the actual overland flow-rate during precipitation to enable NPS quantification. However due to the limited time and resources, the overland flow or runoff volume had to be estimated from various literary sources taking into consideration a margin of safety. The primary method engaged was the *Rational Method*, which relates peak runoff to rainfall intensity through a proportionality factor. The Rational Formula is one of the most frequently used urban hydrology methods in Malaysia. The formula is [5];

$$Q_y = \frac{C \cdot I_y \cdot A}{360}$$

where;

- $Q_y$ = y year ARI peak flow (m$^3$/s)
- $C$ = dimensionless runoff coefficient (determined to be 0.67 (medium soil forest) and 0.78 (medium soil open crop) [6])
- $I_y$ = y year ARI average rainfall intensity, mm/hr (determined to be 95 mm/hr for 100 year return period [7])
- $A$ = drainage area, ha (500 acre = 202.35 ha ≈ 203 ha (total project site))

The overland flow was calculated to be at about 40 m$^3$/s for the total project area; however, the actual area under development varies from year to year depending on how much rainwater was reused and is a direction function of the area undergoing development as depicted in Table 2. The residual overland flow was distributed on selected reaches of the Sg. Bertam main stem in accordance with the land area for each sub-catchment (Figure 3).
The hyetograph for Brinchang is as depicted in Figure 3. The above assumptions and calculations already take into account worst-case-scenario conditions of the probable overland flow. The dimensionless runoff coefficient constitutes bare runoff losses as a result of infiltration and percolation, which in turn translates to maximum runoff volume and surface pollutant absorption. The rainfall intensity of 95 mm/hr for 100 year return period also depicts maximum volumetric runoff that can occur, whilst still producing a runoff coefficient close to the 59 mm/hr precipitation (5 year return period).

Results & Discussion
This section entails discussion pertaining to the modeling exercise. Essentially, the impact towards Sg. Bertam will be scrutinized under two separate conditions relevant to two separate impacts. The first, of course being the sewage impact during the operational phase of the administration building under conventional flow conditions and the second; and perhaps more critically is the impact from runoff as a result of construction and daily activities.

Sewage Impact
For BOD$_5$, the modeling results indicated that the proposed septic tank discharge would not adversely affect the ambient water quality of Sg. Bertam if Standard B compliance was maintained at all times at the prescribed peak discharge flow of 0.003 m$^3$/s (Figure 4). This was unsurprising, since the proposed ambient PE is relatively marginal in comparison to the ambient flow. In addition Sg. Bertam is already denoted as a Class III river (in terms of BOD) under the INWQS as a result of pollution input from point and non-point sources within the surrounding area, which in turn, results in a “masking” effect of the effluent discharge. Even if raw effluent was released, the difference would still be relatively marginal. This was a good example of how the septic tanks’ volumetric load failed to overwhelm the rivers’ natural dilution capacity. Only in the event of disaster, from shock-loading (high volumetric discharge, ten times normal) would the ambient water quality deteriorate to Class V.
Table 2: Runoff Allocation for Each Sub-Catchment

<table>
<thead>
<tr>
<th>Stream</th>
<th>Total Catchment Area (ha)</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011 onwards</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (ha)</td>
<td>Q (m³/s)</td>
<td>Area (ha)</td>
<td>Q (m³/s)</td>
<td>Area (ha)</td>
</tr>
<tr>
<td></td>
<td>1st Year</td>
<td>2nd Year</td>
<td>Cumulated</td>
<td>3rd Year</td>
<td>Cumulated</td>
</tr>
<tr>
<td>Stream A</td>
<td>22.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEF</td>
<td>0</td>
<td>0</td>
<td>1.30</td>
<td>0.04</td>
<td>4.20</td>
</tr>
<tr>
<td>OPEN FARM</td>
<td>2.90</td>
<td>0.36</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Undeveloped area</td>
<td>19.41</td>
<td>4.00</td>
<td>18.11</td>
<td>3.73</td>
<td>18.11</td>
</tr>
<tr>
<td>Total</td>
<td>22.31</td>
<td>4.35</td>
<td>19.41</td>
<td>3.77</td>
<td>22.31</td>
</tr>
<tr>
<td>Stream B</td>
<td>102.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEF</td>
<td>18.30</td>
<td>0.57</td>
<td>3.60</td>
<td>0.11</td>
<td>36.10</td>
</tr>
<tr>
<td>OPEN FARM</td>
<td>14.20</td>
<td>1.75</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CPPC</td>
<td>1.00</td>
<td>0.24</td>
<td>0</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Undeveloped area</td>
<td>68.97</td>
<td>14.20</td>
<td>65.37</td>
<td>13.46</td>
<td>65.37</td>
</tr>
<tr>
<td>Total</td>
<td>102.47</td>
<td>16.75</td>
<td>68.97</td>
<td>13.57</td>
<td>102.47</td>
</tr>
<tr>
<td>Stream C</td>
<td>63.46</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEF</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.70</td>
</tr>
<tr>
<td>OPEN FARM</td>
<td>1.70</td>
<td>0.18</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Undeveloped area</td>
<td>61.76</td>
<td>10.92</td>
<td>61.76</td>
<td>10.92</td>
<td>61.76</td>
</tr>
<tr>
<td>Total</td>
<td>63.46</td>
<td>11.10</td>
<td>61.76</td>
<td>10.92</td>
<td>63.46</td>
</tr>
<tr>
<td>Stream D</td>
<td>15.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undeveloped area</td>
<td>15.18</td>
<td>2.68</td>
<td>15.18</td>
<td>2.68</td>
<td>15.18</td>
</tr>
<tr>
<td>Total</td>
<td>15.18</td>
<td>2.68</td>
<td>15.18</td>
<td>2.68</td>
<td>15.18</td>
</tr>
</tbody>
</table>
Referring to Figure 5, the TSS pattern also did not depict any discernable changes in ambient concentration when Standard B compliance is achieved. The TSS levels were considered to be relatively good, within Class II of the INWQS. Again, even in the event of raw sewage being discharged at the default flowrate, the change in ambient loading would not significantly deteriorate the ambient levels. This was another testament to the relatively minute contribution of the septic tank towards Sg. Bertam. For the STP failure scenario, the ambient TSS concentration would hover close to the Class III threshold before further dilution after confluences with Stream C and D.
The above downstream concentration profile also held true for the nitrogen species modeled, ammoniacal nitrogen and nitrate. Although being the case, some deterioration in ambient AN levels were observed if the proposed discharge quality of 20 mg/l (Standard B) was met, though still being within the Class II limit. Realistically, though, the discharge quality of 20 mg/l is typical (if not barely achievable) for conventional treatment systems such as septic tanks. Therefore, it would be prudent for the project proponent to ensure that the septic tank is properly maintained and de-sludged throughout its operational capacity. In addition, if untreated effluent was discharged, into Sg. Bertam a Class III denotation may be imminent downstream, whereas the system failure scenario, resulted in Class V classification. Based on these observations, it can be extracted that Sg. Bertam, is a sensitive towards ammoniacal nitrogen input.

High levels of nitrate seemed to be native to Sg. Bertam and its tributaries (3-5 mg/l), as exhibited by the field survey results. The nitrate most likely originated from agricultural activities taking place within Bertam Valley, where NO$_3^-$ is a common element in fertilizers as well as phosphorous (P). Anomalously, no distinct levels of ammonium (NH$_4^+$), another component typically found in fertilizers (such as ammonium nitrate) was detected (refer Figure 6), except under high flow conditions (W4 = 0.42 mg/l). This may be attributed to either active nitrifying processes or simply due to the type of fertilizer used.

Anyway, a similar “masking” effect of the nitrate discharge from the septic tank was observed for all the scenarios modeled, except for the load shock scenario (Figure 7). Even under these circumstances, the nitrate levels only peaked close to 7 mg/l, which in turn was still lower than the ambient concentration value during high flow conditions (W4 = 9.22 mg/l). This observation reinforces the hypothesis that nitrate presence in Sg. Bertam was predominantly from agricultural sources, i.e., organic fertilizer. The same is true for phosphorous (Figure 8). High levels of phosphorous, within the catchment, entailed a similar pattern, where elevated levels were detected basin-wide, particularly during high-flow conditions. Worst still, the load shock scenario only depicted a marginal difference relative to the current ambient concentration as opposed to the Standard B compliance and Raw Sewage discharge scenarios, where relatively no discrepancy was seen. To simplify, the impact of AN, NO$_3^-$ and P from the septic tank towards ambient levels under normal discharge flow conditions would be relatively marginal, except under extraordinary circumstances where the treatment system would rupture resulting in a sudden increased volumetric discharge; would the ambient water quality of Sg. Bertam be seriously affected.
Finally, *E. coli* was modeled as coliform in QUAL2E. It is a bacterium that is commonly found in the lower intestine of warm-blooded animals. Virulent strains of *E. coli* can cause gastroenteritis, urinary tract infections, and neonatal meningitis. In rare cases, virulent strains are also responsible for peritonitis, mastitis, septicemia and Gram-negative pneumonia [8].

The high and random die-off rate (effected by a host of physical, chemical and biological factors) of *E. coli* bacterium makes it a difficult constituent to model, often with deviations of above fifty percent. The best approach therefore should be a conservative one, with a die-off temporal rate of 0.0625/hr (1.5/day) [9] and various discharge test scenarios. It should also be noted also that the INWQS does not specify colony forming units (cfu) for *E. coli* but rather *Fecal Coliform*. Although not entirely accurate, this can be used as a guide in assessing *E. coli* presence in ambient water with a ratio of about 0.77 FC_{gm}/EC_{gm} [10]. In watershed management, the primary objective
however, should always be in causing as little disturbance as possible with regards to the current ambient colony count. The *E. coli* modeling results indicated that impact on the ambient water quality would be fairly minimal if the effluent colony count were not to exceed 10,000 cfu/100 ml (Figure 9). Raw effluent discharge (50,000 cfu/100 ml) would cause a relatively significant increase in bacterial population within the stream even at the default discharge flowrate of 0.003 m$^3$/s; at about 500 cfu/100 ml downstream. This was due to the significant margin in populous count between treated and untreated sewage. Again the forcing function behind the modeling results was the effluent volumetric flow. If the hypothetical load is maintained then the impact towards downstream water quality in terms of *E. coli* should be relatively minimal.

**Figure 9: *E. coli* Septic Tank Impact (Peak Operating Capacity)**

**Runoff Impact**
Runoff impact from agricultural sources remained relevant towards Sg. Bertam due to the potential organic s harvested and fertilizers used within the vicinity of the project site, which may be carried off by the overland flow or runoff. Since the operational and developmental phases of the project would be in stages, it was relevant to simulate each stage to ascertain potential impacts as a result thereof (refer Table 2). Modeling for the baseline condition as a benchmark, was rather tricky considering the nearby road construction works within the Bertam Valley greatly influenced the resulting ambient water quality (and thus sampling results) during precipitation, particularly for TSS. Therefore the modeling results can serve as a reference in relation to the sampling event and not for the actual base condition when development is completed. It should also be noted that the resulting water quality may also fluctuate, as a function of the runoff characteristics and quality from the road construction site, depending on the level of completion. For modeling purposes the septic tank was modeled at Standard B compliance at default flow conditions.

Referring to Figure 10, the BOD$_5$ runoff impact was a predominant function of runoff from the upper reaches on the Sg. Bertam main-stem. This was testament to the influence of other potential pollution sources within Bertam Valley from a general perspective (activities upstream); or more specifically from the road works. Although there was not much difference in terms of BOD$_5$ ambient concentration during low and high flow occasions, under normal conditions, one would typically expect a significant dilution effect of the ambient BOD$_5$ concentration due to immense inflow, instead the ambient value remained fairly steady, with relatively marginal decreases after tributary confluences. Implicitly this was implying the stronghold of agricultural runoff although not deteriorating; remained significant. In terms of sewage impact, no deterioration was observed under high flow conditions. Moving temporally there was also not much difference in terms of BOD$_5$ impact during the con-current construction and operation of the project.
For TSS, several varying outcomes were observed during the peak runoff occasion as shown in Figure 11. The construction phase of the proposed project could result in immense deterioration of the ambient water quality of up to 2,000 mg/l for TSS, on the downstream reaches if specific control measures are not met. The current ambient concentration is between 300 - 600 mg/l at W4. Of course this hypothesis only holds true if the current TSS contribution from the surrounding road works remain continuously contributing. Year 2008 exhibited the highest concentration simply because it is during this time that most of the earth works will be taking place within the project area. Further reduction was seen in 2009 as more area is developed. 2010 exhibited the lowest contribution, as lesser land area is developed followed by an increase in 2011. After all of the land area is developed (post-2011), the project site will become more stable resulting in improvement of ambient TSS. The critical period therefore would be during the project’s construction phase. The uncontrolled emission of TSS as a result of runoff would not only cause deterioration in ambient concentration, but particle settling will contribute towards an increase in sediment depth thus resulting in a shallower river bed. This was especially true for the incoming side stream of Sg. Bertam, particularly Stream B, as most of the land area is developed here.

It is therefore recommended that a series of silt traps be constructed for each of the receiving tributaries to deal with this potential problem. Construction of silt traps with at least 70% removal efficiency (1,500 mg/l) would result in a significant reduction of the TSS runoff quality as shown below, albeit still insufficient in returning the ambient values to “normal”. The silt traps should be constructed in tandem with the specific area undergoing development to capture any potential sediment carry off. In addition it would also be prudent for the project proponent to cover exposed earth with polymer canvases/other impermeable cover in the specific construction site during a precipitation event.

Referring to Figure 12, the ambient ammoniacal nitrogen levels remained fairly good throughout the basin, even better than the low-flow instance as a result of runoff dilution. However there was an anomalous peak towards the end of the Sg. Bertam main-stem, which was probably due to input from agricultural sources within the vicinity. As discussed previously, it was rather surprising that the ammoniacal nitrogen levels remained fairly good throughout the basin as ammonium is a common constituent in fertilizers. Impact from the project site can be considered minimal, as long as the fertilizer used did not contain significant levels of ammonium, comparable to the current situation. Monitoring of the runoff characteristics and river water quality during the EMP (construction phase) would enable a more comprehensive understanding of AN behavior within the basin and therefore further assist in expediting a remediation strategy.
The ambient levels of nitrate exhibited rather significant decrease post-project implementation as shown in Figure 13, albeit still remaining fairly high (6 mg/l), particularly on the upstream reaches. Tributary confluences however resulted in the concentration diminishing moving downstream (5 mg/l).

Two interesting observations were made here; one; there seemed to be an increase in ambient nitrate levels, though not too distinct, as more phases of the project was completed, from year 2008 to 2011. This was directly attributed to the reticulated flow concept of the proposed project in relation to irrigation and watering of crop. As a result lesser runoff was going to the river, decreasing the dilution capacity during high flow occasion. Thus any future plans pertaining to water requirements on-site should take this factor into consideration (e.g., dam construction).
Second; while there was an observable reduction in nitrate values, the predominant influencing factor was still the surrounding agricultural activities. Although lesser amounts of nitrate were ending up in the runoff, the influence of other uncontrolled agricultural activities within the surrounding area and upstream, significantly contributed towards the ambient nitrate levels.

A similar trend was observed for phosphorous, where natively; the ambient levels remained relatively high, even under high flow conditions as depicted in Figure 14, (about 5 mg/l at W4), though comparative to the low-flow conditions, some dilution was seen. The improvement between current and predicted ambient concentration at different phases of the project however was marginal (<15%). Again, the primary pollution contributor was agricultural activities within the surrounding area.
Conclusion and Recommendations

Several key points can be concluded from the modeling exercise:

- Compliance to Standard B of the Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979, Environmental Quality Act 1974 would be sufficient in preserving the ambient water quality of Sg. Bertam for the relevant parameters modeled for constituents originating from the septic tank.
- It is also recommended that the ammoniacal nitrogen, nitrate and phosphorous concentration from the proposed septic tank effluent not exceed 20 mg/l at any time during its operational phase.
- For \( E. \ coli \), a populous count of 10,000 cfu/100 ml or less in the effluent must be achieved to avoid bacterial contamination along the main stem of Sg Bertam.
- To adhere to the above recommendations, the septic tank must follow a strict maintenance and de-sludging schedule, monitored by relevant authorities, throughout the course of the project (construction and operational phases).
- Silt traps must be available throughout the construction phase to avoid excessive TSS runoff and deposition. The runoff should be channeled towards each silt trap. Also, the silt traps must be site specific and relative to each development phase (particularly Stream B that experiences the most development).
- The effluent runoff quality from the silt trap must not exceed 1,500 mg/l at any time during precipitation and the silt traps must be properly maintained with frequent removal of accumulated sediment to ensure maximum removal efficiency is achieved.
- It is also recommended that loose soil as a result of the earth works carried out, be properly covered during precipitation by using an impermeable surface (e.g., polymer canvas) to minimize sediment transport relative to each area undergoing construction.
- Frequent ambient water quality monitoring during the construction and operational phases of the project should be captured in the Environmental Management Plan (EMP) of the site, for both low flow and high flow conditions.
- A quarterly (every 3 months) Environmental Audit (EA) throughout the construction phase is recommended to monitor the actual impacts from the project site as well as the maintenance of silt traps. The audit committee should consist of representatives from the prescribed authoritative body (DOE), a stakeholder representative (REACH), the project proponent and EMP consultant.
- A monthly sampling exercise for relevant parameters including, DO, BOD\(_5\), COD, TSS, AN, Nitrite, Nitrate, Phosphorous, \textit{Fecal Coliform}, \textit{Total Coliform} and \( E. \ coli \) should be conducted at each of the receiving streams and reported to the Department of Environment (DOE); as the primary authoritative body and Regional Environmental Awareness Cameron Highlands (REACH); as a stakeholder representative.
- In addition, sediment transport modeling of the study area would prove beneficial towards stream bed depth characterization and preservation.
- Although the project concept is based on reticulated flow, the existence of a pre-treatment system (e.g. retention pond) as a backup measure for potential runoff occurring from the project site would be prudent.
- Pesticides and herbicides are difficult constituents to model due to the various factors involved, including, variations in the type of pesticide used, its trace level characteristics, infiltration rate and runoff absorption properties. However, as an indicator for pesticide management in watersheds designated for potable water supply; the National Drinking Water Quality Standard (NDWQS) Recommended Standard 1(a) should be a strong basis, where essentially no pesticides or herbicides should be present at all. Therefore, it is strongly recommended that pesticide and herbicide handling within the project site be emphasized at all times. Bags or containers containing the constituents should not be exposed to precipitation at any time, to avoid runoff contamination. In addition a proper facility for storage should be set-up and any activity pertaining to potential spillage or sipping into Sg. Bertam or its tributaries should be avoided.
References


