BENTHIC MACROINVERTEBRATE/ WATER QUALITY

Overview

The Department of ecology (Ecology) role in this project was to use benthic macroinvertebrates as an indicator of overall reach or pond habitat quality, and relate biological condition to its environment.

The key questions associated with this study are:

What impacts do gravel pits located adjacent to the Yakima River have on benthic communities, fish assemblages, temperature, and geomorphology?

The Ecology contribution to address this question is to determine whether or not the benthic macroinvertebrate assemblages downstream from the gravel pits vary from assemblages upstream from the pits.

What are the impacts, design factors and criteria associated with implementing connection or continued isolation of existing pits?

The Ecology contribution to address this question is to 1) compare upstream/downstream variability of benthic macroinvertebrate assemblages in the three avulsed sites and relate the variability in the downstream receiving waters to any physicochemical impacts, and 2) rank the benthic macroinvertebrate condition in the isolated pit ponds and relate the condition to pond water quality.

What factors should be considered in siting, designing, permitting and future use of new floodplain gravel pits?

The Ecology contribution to address this question is to determine possible physicochemical impacts on 1) pond water quality and biological integrity, and 2) avulsed pit pond water quality and biological integrity in the historical pit location and receiving waters. These questions will be addressed by all study partners together in a more comprehensive fashion after the interim phase of reporting.

Methods

Sampling Design and Sites

Three replicate samples were collected from each gravel pit using gravel baskets. At each pit location, four replicates were collected at locations upstream from and downstream of each pit, respectively (Appendix 1). Thus, a total of eleven macroinvertebrate samples were collected from each gravel pit site. The upstream samples represented control locations. Future monitoring will able to determine what, if any, changes have occurred at the downstream river reach when the gravel pits are reconnected to the river. Macroinvertebrate communities may indicate the type of
pollutants (e.g., adsorbed contaminants, sedimentation) that are input to receiving water. Macroinvertebrate community composition, along with trophic state and macrophyte assessments, will rate each pit, in terms of productivity and biological integrity.

Community-level expressions (biometrics) were generated for each macroinvertebrate sample and compared to others for changes that are related to chemical and physical alterations. The relationship between physical variables and the biotic community were further analyzed to determine which key variables in the riverine environment influence condition of aquatic life.

River Field Procedures

River field procedures for benthic macroinvertebrates conformed to standard Ecology protocols (Plotnikoff and Wiseman 2001). Because evaluation of the gravel pit influence on the mainstem river was confined to pit length, the reach lengths were approximately 10-15 wetted widths instead of the standard 40 widths for mid-order streams. Therefore, localized effects were measured. Physicochemical methods for river surveys are outlined in Table 1.

Benthic macroinvertebrate samples were stored in 80% ethanol and transported to a contract laboratory for identification. The samples were sorted to a 500-count and the lowest practical taxonomic effort was employed (Plotnikoff and Wiseman 2001).

Table 1. Methods for river and pond bioassessment and habitat surveys.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Study Application</th>
<th>Method</th>
<th>Accuracy</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lotic Benthic Macroinvertebrate Collection</td>
<td>River</td>
<td>Replicated Kicknet Sampling</td>
<td>NA</td>
<td>Plotnikoff and Wiseman (2001)</td>
</tr>
<tr>
<td>Canopy Cover</td>
<td>River</td>
<td>Concave Densiometer</td>
<td>NA</td>
<td>Plotnikoff and Wiseman (2001)</td>
</tr>
<tr>
<td>Substrate Grid Counts Wetted and Bankfull Width</td>
<td>River</td>
<td>50-pt Grid</td>
<td>NA</td>
<td>Plotnikoff and Wiseman (2001)</td>
</tr>
<tr>
<td>Gradient</td>
<td>River</td>
<td>Laser Range Finder</td>
<td>Forthcoming</td>
<td>Plotnikoff and Wiseman (2001)</td>
</tr>
<tr>
<td>Current Velocity</td>
<td>River</td>
<td>Marsh-McBirney Meter</td>
<td>Forthcoming</td>
<td>Plotnikoff and Wiseman (2001)</td>
</tr>
<tr>
<td>Pond Benthic Macroinvertebrate Collection</td>
<td>Pond</td>
<td>Artificial Substrate Sampling</td>
<td>NA</td>
<td>Rosenberg and Resh (1982)</td>
</tr>
<tr>
<td>Macrophyte Survey</td>
<td>Pond</td>
<td>Qualitative Survey</td>
<td>NA</td>
<td>Parsons (2001)</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>River and Pond</td>
<td>Idiometric, with Azide Modification</td>
<td>0.1 mg/L</td>
<td>4500 OC (APHA 1998)</td>
</tr>
<tr>
<td>Temperature</td>
<td>River and Pond</td>
<td>Alcohol Thermometer or Long-Line Thermistor</td>
<td>0.1 C</td>
<td>2550 (APHA 1998)</td>
</tr>
<tr>
<td>Conductivity</td>
<td>River and Pond</td>
<td>Electrode</td>
<td>1 umhos/cm</td>
<td>2510 (APHA 1998)</td>
</tr>
<tr>
<td>pH</td>
<td>River and Pond</td>
<td>Glass Electrode</td>
<td>0.1 unit</td>
<td>4500 H+ (APHA 1998)</td>
</tr>
</tbody>
</table>
### Pond Field Procedures

Pond field methods are outlined in Table 1. Together, the pond parameters comprise a Tier 2A Biological Assemblage Assessment (EPA 1998). Gravel baskets were used to collect benthic macroinvertebrates because the coarse benthic sediments excluded the use of traditional grab samplers (Ponar, Eckman, etc.). The Gravel baskets were comprised of ## L of 2”- round gravel. The baskets were deployed in the fourth week of July, 2002. In order to avoid collecting invertebrates associated with vascular plants, the baskets were placed just past (i.e. deeper than) the emergent macrophyte zone. In some ponds, floating macrophytes were ubiquitous. In these cases, the baskets were placed in pockets where the plants appeared to be absent. Approximately 6 weeks were allowed for colonization of the gravel baskets. In September, the baskets were retrieved with the aid of a 500 um mesh dip-net. The baskets were temporarily stored in coolers with pond water. Later in the day, the macroinvertebrates were sorted out of the gravel, stored in 80% ethanol and transported to a contract laboratory for identification. The samples were sorted to a 500-count and the lowest practical taxonomic effort was employed (Plotnikoff and Wiseman 2001).

Water Quality and qualitative macrophytes surveys (Parsons 2001) were conducted in each pond on the same day of gravel basket retrieval. Temperature profiles were taken at approximately the deepest point in each pond with 0.5 m intervals. Dissolved oxygen, pH, and conductivity measurements were taken at 0.5 m from the surface and near the bottom of the profile. Orthophosphorus, Total Phosphorus, Total Kjeldahl Nitrogen, Total Dissolved Solids, and Chlorophyll a measurements were only taken at 0.5 m from the surface.

### Data Quality Objectives

Benthic macroinvertebrate community characterizations were used to determine the influence gravel pits have on both adjacent stream and interior pit biota. Sampling must capture representative conditions at each sample site. Replicate samples were collected throughout each gravel pit site. Replicates were intended to measure the precision in field sampling and the variability associated with the natural "clumping" distribution in the macroinvertebrate communities. Replicates were collected from riffle habitat at the river and from within the gravel pits. Use of double nested freezer bags and adequate labeling of each bag were employed to minimize sample loss (i.e. to maximize completeness). To be comparable with other regional studies, standardized sampling

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phosphate</td>
<td>Ascorbic Acid Method</td>
<td>Forthcoming 4500 PE (APHA 1998)</td>
</tr>
<tr>
<td>Ortho-Phosphate</td>
<td>Ascorbic Acid Method</td>
<td>Forthcoming 4500 PE (APHA 1998)</td>
</tr>
<tr>
<td>Total Nitrogen (Kjeldahl)</td>
<td>Kjeldahl Method</td>
<td>Forthcoming 4500 NB (APHA 1998)</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>Total Dissolved Solids Dried at 180 °C</td>
<td>Forthcoming 2540 C (APHA 1998)</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>Fluorometric</td>
<td>Forthcoming 10200 (APHA 1998)</td>
</tr>
</tbody>
</table>
methods were used in the respective habitat types.

Macroinvertebrate laboratory data quality objectives cover the sorting, enumeration, and identification process. Precision of the sorting process is evaluated by resorting 20% of the original samples or having an independent technician examine the sorted residue for additional organisms. Sorting efficiency is calculated by the sort count divided by the sort count plus the organisms overlooked. The sorting efficiency for this project was expected to be no less than 97%. No problems with enumeration and identification accuracy were expected. To control for possible mistakes, 10% of the original samples were vouchered and exchanged among four professional taxonomists for verification and standardization of identifications.

Water quality data quality objectives are outlined in Table 1. These were verified by using check standards and taking field duplicate samples.

**Data Analysis**

**Pond Water Quality**

Temperature stratification was noted. Deleterious DO, temp, and pH conditions were noted and related to secchi depth, nutrient, chla, and TDS values.

**Pond Biology**

Invasive macrophyte presence was noted. Comments on macrophytes community structure and anomalies were also noted.

Different biometric expressions of benthic macroinvertebrate community condition were calculated and used to rank pond biological health (See Appendix 2 for biometric explanations). Biological condition was qualitatively related to water quality. Pond biological condition was also used as a benchmark to determine if the biological condition of the avulsed ponds changed to a condition more indicative of a lotic (moving water) habitat.

**River Physicochemical**

Temperature, Dissolved oxygen, pH, and Conductivity were correlated with elevation and river mile. Large upstream/downstream differences were noted.

Stacked bar graphs were constructed to compare the substrate distribution between each pair of reaches. Non-parametric Mann-Whitney U tests were run to see if the gradient, canopy cover, average depth, average velocity, bottom velocity wetted width, and bankfull widths were significantly different between each pair of reaches. The Mann-Whitney U is non-parametric, and tests the differences between the variability of two populations.
**River Biology**

In order to identify biologically similar reaches, all eighty river macroinvertebrate samples were clustered with a Bray-Curtis similarity measure and an average linkage metric. The Bray-Curtis similarity measure minimizes the influence of common species absences between samples. Species data in each sample were log (x+1) transformed. Cluster classes were compared to 1) orientation to the gravel pit (i.e. above or below), 2) elevation, and 3) river mile.

Metrics describing richness, composition, trophic status, and tolerance attributes of the benthic macroinvertebrate community were used as univariate endpoints. Non-parametric Mann-Whitney U tests were run on each metric with orientation to the gravel pit (i.e. above or below) as the treatment. Non-parametric pairwise correlations between the metrics, elevation, and river mile were also calculated.

Finally, in order to verify the relationship between physicochemical variables and biological condition, Canonical Correspondence (CCA) axes were generated using the log (x+1) transformed species data matrix. All physicochemical variables deemed to be relevant to biological condition from prior analyses were included in the CCA.

**Results: General**

*Data Quality Objectives*

From the 110 potential river and pond macroinvertebrate samples, only 3 pond samples were lost in the field. This was probably due to vandalism of the gravel baskets. The Coefficient of Variability of river and pond replicate macroinvertebrate taxa richness was 12.4% and 26.2%, respectively. The greater variability of the pond replicates was probably greater because of the higher variability of the pond habitat and difficulty in sample collection. Taxonomic sorting efficiency was approximately 97%. Out of the 107 samples processed, only 3 taxa needed to be confirmed by senior taxonomists. The ambiguities were rectified by the senior taxonomists. Water quality accuracy and precision are listed in Table 2.

Table 2. Water quality accuracy and precision results.

<table>
<thead>
<tr>
<th></th>
<th>Accuracy</th>
<th>Average Difference between Field Replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Conductivity</td>
<td>1.1</td>
<td>0.8</td>
</tr>
<tr>
<td>DO</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Total Phosphate</td>
<td>Forthcoming</td>
<td>NA</td>
</tr>
<tr>
<td>Ortho-Phosphate</td>
<td>Forthcoming</td>
<td>NA</td>
</tr>
<tr>
<td>Total Nitrogen (Kjeldahl)</td>
<td>Forthcoming</td>
<td>NA</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>Forthcoming</td>
<td>NA</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>Forthcoming</td>
<td>NA</td>
</tr>
</tbody>
</table>
**Pond Benthic Macroinvertebrates**

Several biometrics were calculated for each pond sample. In order to minimize redundancy, three uncorrelated biometrics, total richness, % top 3 taxa, and the Hilsenhoff Biotic Index (HBI) were selected. The HBI is a biological indicator of biological enrichment. As environmental conditions deteriorate for macroinvertebrates, total richness should decrease, while % top 3 taxa and the HBI scores should increase (Appendix 2). The avulsed Terrace Heights and Gladmar ponds ranked the highest for all three biometrics (Table 3). The avulsed Parker ponds had mediocre scores, which suggest that it still retains biological qualities of isolated ponds.

Table 3. Selected biometrics with scores ranked from best to worst.

<table>
<thead>
<tr>
<th>Site</th>
<th>HBI</th>
<th>Site</th>
<th>total richness</th>
<th>Site</th>
<th>%top3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gladmar Pond</td>
<td>4.1</td>
<td>Terrace Heights Pond</td>
<td>38</td>
<td>Terrace Heights Pond</td>
<td>0.50</td>
</tr>
<tr>
<td>Terrace Heights Pond</td>
<td>5.7</td>
<td>Gladmar Pond</td>
<td>35</td>
<td>Gladmar Pond</td>
<td>0.54</td>
</tr>
<tr>
<td>Hanson Pond</td>
<td>6.0</td>
<td>I-90 Pond 4</td>
<td>23</td>
<td>I-90 Pond 5</td>
<td>0.62</td>
</tr>
<tr>
<td>Selah Pond</td>
<td>6.1</td>
<td>Parker Ponds</td>
<td>21</td>
<td>Parker Ponds</td>
<td>0.66</td>
</tr>
<tr>
<td>Edler Ponds</td>
<td>6.5</td>
<td>Edler Ponds</td>
<td>20</td>
<td>DeAtley Pond</td>
<td>0.66</td>
</tr>
<tr>
<td>I-90 Pond 4</td>
<td>7.1</td>
<td>DeAtley Pond</td>
<td>18</td>
<td>Hanson Pond</td>
<td>0.70</td>
</tr>
<tr>
<td>Newland Pond</td>
<td>7.4</td>
<td>Hanson Pond</td>
<td>16</td>
<td>Edler Ponds</td>
<td>0.79</td>
</tr>
<tr>
<td>DeAtley Pond</td>
<td>7.5</td>
<td>I-82 Pond 5</td>
<td>15</td>
<td>Parker Ponds</td>
<td>0.79</td>
</tr>
<tr>
<td>Parker Ponds</td>
<td>7.5</td>
<td>Newland Pond</td>
<td>10</td>
<td>Selah Pond</td>
<td>0.81</td>
</tr>
<tr>
<td>I-82 Pond 5</td>
<td>8.1</td>
<td>Selah Pond</td>
<td>8</td>
<td>Newland Pond</td>
<td>0.83</td>
</tr>
</tbody>
</table>

**Pond Macrophytes - by Jenifer Parsons**

Data are in Appendix 3

**Invasive Species**

Several non-native invasive plant species were identified in the gravel pit ponds inventoried as part of this project. The submersed weed Myriophyllum spicatum (Eurasian watermilfoil) is the dominant plant in I-82 Pond 5. Another non-native submersed species, Potamogeton crispus (curly leaf pondweed), was found in Pond 5, Parker Pit, Edler Ponds, Newland Pit, Selah Pit, and I-90 Pond 4. This species is widespread in central Washington, and usually does not dominate the submersed community the way Eurasian milfoil and other invasive species do.

The non-native floating leaved plant fragrant water lily (Nymphaea odorata) was found in small patches in the Parker ponds. This plant often dominates areas with shallow water and soft substrate, and it is very dense in a few of the other ponds at this Parker Pit that do not have flowing water.

Several non-native invasive emergent plants were noted along the shores of the ponds. Lythrum salicaria (purple loosestrife) was found at Pond 5, the Parker Pit, Edler Ponds, Newland Pit, East Selah Pit, and I-90 Pond 4. Iris pseudacorus (yellow flag iris) was
found at the Edler Ponds and East Selah Pit. Phalaris arundinacia (reed canarygrass) is a widespread weed, and was found at I-82 Pond 5, Edler Ponds, East Selah Pit, I-90 Pond 4, Gladmar Pit and Hanson Pond. One species with both native and invasive genotypes in Washington, Phragmites australis (common reed), was found at the De Atley Pit. It is not known if this is the invasive variety, however large stands of invasive Phragmites are located along the wetlands of the lower Snake River, a fairly shore distance away.

General Observations

The species assemblages in some of the gravel pit ponds were unusual. The Newland Pit has a large population of the water clover Marsilea in shallow water along most of the shoreline. This plant is usually found in wetlands, and while it is not uncommon in central Washington, we have never before observed it on a lake shore. The East Selah Pit has the densest growth of the native plant Heteranthera dubia ever witnessed in a Washington waterbody. In fact, this plant was once thought to be scarce enough to be included on the list of endangered, threatened and sensitive vascular plant of Washington. The Hanson Pond we inventoried also was unusual in the dominance of Potamogeton amplifolius, a plant that usually grows in a mixed pondweed community. Perhaps the relative young age of these ponds has allowed the first plants to colonize them do dominate in a way they wouldn’t if a more diverse macrophyte community were present.

Two of the ponds (DeAtley and Edler Ponds) were experiencing cyanobacteria blooms (blue green algae) at the time of the inventory. These ponds also seemed to have a lower diversity of submerged macrophyte species than the other ponds, possibly due to the dominance of algae and the concurrent reduction of light available to submerged macrophytes.

River Water Quality

Conductivity and temperature decreased with increasing elevation and river mile (Table 4). Temperature and pH tended to increase with conductivity, although these correlations are most likely spurious. Temperature is probably a function of natural and anthropogenic downstream warming. Increased pH is probably caused by higher primary production in the lower Yakima, where conductivity is also higher. Finally, pH tended to increase with dissolved oxygen (Table 4). Inputs of nutrients, (e.g. from agricultural return drains) may have cause localized spikes in primary production, could have increased DO and pH during daylight hours.

Table 4. Non-parametric correlations between river water quality parameters, elevation, and river mile.

<table>
<thead>
<tr>
<th></th>
<th>Spearman's Rho</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>Temperature</td>
<td>-0.53</td>
</tr>
<tr>
<td>Elevation</td>
<td>Cond</td>
<td>-0.73</td>
</tr>
<tr>
<td>RM</td>
<td>Temperature</td>
<td>-0.53</td>
</tr>
<tr>
<td>RM</td>
<td>Cond</td>
<td>-0.73</td>
</tr>
<tr>
<td>Cond</td>
<td>pH</td>
<td>0.52</td>
</tr>
<tr>
<td>Cond</td>
<td>Temperature</td>
<td>0.51</td>
</tr>
<tr>
<td>DO</td>
<td>pH</td>
<td>0.33</td>
</tr>
</tbody>
</table>
River Biology

Every biometric indicated that biological condition worsens from upstream to downstream (Table 5). This trend is supported by adjacent reaches being biologically similar in terms of the species similarity (Figure 1).

Table 5. Rank correlation of biometrics with river mile (RM) and elevation. By definition, RM and elevation have a perfect rank correlation.

<table>
<thead>
<tr>
<th>Biometric</th>
<th>Spearman's Rho</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intolerant Richness</td>
<td>0.477658093</td>
<td>0.000001</td>
</tr>
<tr>
<td>Clinger Richness</td>
<td>0.454236805</td>
<td>0.000001</td>
</tr>
<tr>
<td>Ephemeroptera Richness</td>
<td>0.204598308</td>
<td>0.014801</td>
</tr>
<tr>
<td>EPT Richness</td>
<td>0.319893897</td>
<td>0.000093</td>
</tr>
<tr>
<td>HBI</td>
<td>-0.517112255</td>
<td>0.000001</td>
</tr>
<tr>
<td>% Tolerant</td>
<td>-0.461164713</td>
<td>0.000001</td>
</tr>
<tr>
<td>% Clingers</td>
<td>0.390216291</td>
<td>0.000001</td>
</tr>
<tr>
<td>% EPT</td>
<td>0.188311681</td>
<td>0.017631</td>
</tr>
<tr>
<td>% Scrapers</td>
<td>0.247285724</td>
<td>0.001827</td>
</tr>
<tr>
<td>Plecoptera Richness</td>
<td>0.530187249</td>
<td>0.000001</td>
</tr>
<tr>
<td>Long-Lived Richness</td>
<td>0.304866016</td>
<td>0.000295</td>
</tr>
</tbody>
</table>
Figure 1. Dendrogram of macroinvertebrate sample similarity. A Bray-Curtis similarity measure and an average linkage metric was used on log (x+1) transformed macroinvertebrate counts.
Relationship between Biology and Habitat

Canonical Correspondence Analysis (CCA) was used to relate biological condition to habitat, or physicochemical variables (Figure 2; Table 6). Elevation, river mile, bankfull width, wetted width, bottom velocity, and average velocity had significant correlations with CCA axes 1 and 2 (P<0.05). Sediment variables and the Above/Below categorical variable were correlated to the axes, but were not significant.

Table 6. Canonical correlations (p<0.05) of physicochemical variables to ordination axes.

<table>
<thead>
<tr>
<th></th>
<th>axis 1 (x-axis)</th>
<th>axis 2 (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>rm</td>
<td>-0.91</td>
<td>-0.11</td>
</tr>
<tr>
<td>elev</td>
<td>-0.89</td>
<td>0.22</td>
</tr>
<tr>
<td>bw</td>
<td>0.34</td>
<td>0.31</td>
</tr>
<tr>
<td>avg_vel</td>
<td>-0.39</td>
<td>ns</td>
</tr>
<tr>
<td>ww</td>
<td>0.30</td>
<td>ns</td>
</tr>
<tr>
<td>bot_vel</td>
<td>-0.35</td>
<td>ns</td>
</tr>
</tbody>
</table>
Figure 2. Canonical Correspondence bi-plot with benthic macroinvertebrae site distribution and major physicochemical vectors.

**Results: Individual Sites**

**Site 1: Hanson Ponds**

Hanson pond had good water quality and was not stratified at the time of sampling (Table 7, Figure 3). The Benthic macroinvertebrate community appeared to be in a condition typical of this lentic habitat.
Table 7. Pond water quality.

<table>
<thead>
<tr>
<th>Site</th>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>pH</th>
<th>Cond (us/cm)</th>
<th>DO (mg/L)</th>
<th>chla (ug/L)</th>
<th>secchi (m)</th>
<th>OP (mg/L)</th>
<th>TDS (mg/L)</th>
<th>TN (mg/L)</th>
<th>TP (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DeAtley</td>
<td>0.5</td>
<td>19.4</td>
<td>9.51</td>
<td>262</td>
<td>15.5</td>
<td>39.68</td>
<td>1</td>
<td>0.282</td>
<td>189.0</td>
<td>27.0</td>
<td>0.370</td>
</tr>
<tr>
<td></td>
<td>3.5</td>
<td>14.2</td>
<td>7.4</td>
<td>280</td>
<td>0.9</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>I-82 Pond 5</td>
<td>0.5</td>
<td>20.5</td>
<td>8.47</td>
<td>119</td>
<td>8.6</td>
<td>3.63</td>
<td>2.9</td>
<td>0.013</td>
<td>88.0</td>
<td>26.6</td>
<td>0.740</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>19.4</td>
<td>7.13</td>
<td>130</td>
<td>2.6</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Parker</td>
<td>0.5</td>
<td>17.5</td>
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<td>9.2</td>
<td>205</td>
<td>9.8</td>
<td>74.93</td>
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<td>0.009</td>
<td>164.0</td>
<td>23.4</td>
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<tr>
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<td>7.7</td>
<td>221</td>
<td>1.3</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Newland</td>
<td>0.5</td>
<td>20.4</td>
<td>7.77</td>
<td>120</td>
<td>8.1</td>
<td>4.70</td>
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<td>0.018</td>
<td>126.0</td>
<td>10.8</td>
<td>0.580</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
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<td>Selah</td>
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<td>171</td>
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<td>1.54</td>
<td>3.5</td>
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<td>65.6</td>
<td>0.400</td>
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<td>11</td>
<td>7.23</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<td>8.46</td>
<td>102</td>
<td>11.9</td>
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<td>1.4</td>
<td>0.016</td>
<td>ND</td>
<td>51</td>
<td>0.17</td>
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<td>18.3</td>
<td>8.14</td>
<td>103</td>
<td>9.5</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Gladmar</td>
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<td>7.53</td>
<td>63</td>
<td>9.5</td>
<td>0.69</td>
<td>-99</td>
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<td>ND</td>
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<td>Hanson</td>
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<td>8.41</td>
<td>70</td>
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<td>3.08</td>
<td>-99</td>
<td>0.021</td>
<td>2.0</td>
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<td>0.07</td>
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<td>17.8</td>
<td>8.34</td>
<td>70</td>
<td>9.8</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Figure 3. Temperature-Depth profiles of each isolated pond.
In the river, both reaches were on the mainstem. Water quality was similar between the upper and lower reaches (Table 8). At the macroinvertebrate sampling locations, the upper reach had significantly coarser substrate (Figure 4), and the lower reach had significantly faster water velocity (Table 9).

Table 8. Water quality at river bioassessment sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Conductivity (uS/cm)</th>
<th>Dissolved oxygen (mg/L)</th>
<th>pH (units)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower DeAtley</td>
<td>09/03/2002</td>
<td>254</td>
<td>8.9</td>
<td>8.59</td>
<td>22.5</td>
</tr>
<tr>
<td>Upper DeAtley</td>
<td>09/03/2002</td>
<td>255</td>
<td>9.5</td>
<td>8.49</td>
<td>23.0</td>
</tr>
<tr>
<td>Lower I-82 Pond 4</td>
<td>09/04/2002</td>
<td>94</td>
<td>4.2</td>
<td>7.39</td>
<td>17.5</td>
</tr>
<tr>
<td>Upper I-82 Pond 4</td>
<td>09/04/2002</td>
<td>95</td>
<td>11.1</td>
<td>8.42</td>
<td>16.5</td>
</tr>
<tr>
<td>Lower Parker</td>
<td>09/04/2002</td>
<td>93</td>
<td>10.3</td>
<td>8.27</td>
<td>17.5</td>
</tr>
<tr>
<td>Upper Parker</td>
<td>09/04/2002</td>
<td>92</td>
<td>10.1</td>
<td>8.46</td>
<td>18.0</td>
</tr>
<tr>
<td>Lower Edler</td>
<td>09/05/2002</td>
<td>91</td>
<td>9.5</td>
<td>7.73</td>
<td>-99.0</td>
</tr>
<tr>
<td>Upper Edler</td>
<td>09/05/2002</td>
<td>91</td>
<td>10.3</td>
<td>7.87</td>
<td>14.2</td>
</tr>
<tr>
<td>Lower Newland</td>
<td>09/17/2002</td>
<td>89</td>
<td>10.6</td>
<td>8.28</td>
<td>16.2</td>
</tr>
<tr>
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<td>09/17/2002</td>
<td>88</td>
<td>9.6</td>
<td>7.33</td>
<td>17.0</td>
</tr>
<tr>
<td>Lower Terrace Heights</td>
<td>09/17/2002</td>
<td>81</td>
<td>9.5</td>
<td>7.39</td>
<td>14.5</td>
</tr>
<tr>
<td>Upper Terrace Heights</td>
<td>09/16/2002</td>
<td>81</td>
<td>10.0</td>
<td>7.79</td>
<td>17.0</td>
</tr>
<tr>
<td>Lower Selah</td>
<td>09/16/2002</td>
<td>136</td>
<td>11.7</td>
<td>8.94</td>
<td>17.0</td>
</tr>
<tr>
<td>Upper Selah</td>
<td>09/17/2002</td>
<td>130</td>
<td>12.2</td>
<td>9.05</td>
<td>16.5</td>
</tr>
<tr>
<td>Lower I-90 Pond 5</td>
<td>09/18/2002</td>
<td>60</td>
<td>10.1</td>
<td>7.32</td>
<td>16.1</td>
</tr>
<tr>
<td>Upper I-90 Pond 5</td>
<td>09/18/2002</td>
<td>60</td>
<td>9.8</td>
<td>7.11</td>
<td>15.0</td>
</tr>
<tr>
<td>Lower Gladmar</td>
<td>09/18/2002</td>
<td>60</td>
<td>10.2</td>
<td>7.63</td>
<td>13.0</td>
</tr>
<tr>
<td>Upper Gladmar</td>
<td>09/18/2002</td>
<td>57</td>
<td>10.2</td>
<td>7.49</td>
<td>13.8</td>
</tr>
<tr>
<td>Lower Hanson</td>
<td>09/25/2002</td>
<td>58</td>
<td>9.8</td>
<td>7.61</td>
<td>13.7</td>
</tr>
<tr>
<td>Upper Hanson</td>
<td>09/25/2002</td>
<td>58</td>
<td>9.9</td>
<td>7.88</td>
<td>15.1</td>
</tr>
</tbody>
</table>
Figure 4. Average substrate composition of macroinvertebrate sampling locations at the Hanson Pond river reaches.

Table 9. Mann-Whitney U tests of diverging physical traits within site pairs.

<table>
<thead>
<tr>
<th>Site</th>
<th>Trait</th>
<th>Mann-Whitney U</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DeAtley</td>
<td>Average Velocity</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>DeAtley</td>
<td>Gradient</td>
<td>0</td>
<td>0.01</td>
</tr>
<tr>
<td>DeAtley</td>
<td>Wetted Width</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>DeAtley</td>
<td>Bankfull Width</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>I-82 Pond 5</td>
<td>Canopy Cover</td>
<td>0.5</td>
<td>0.03</td>
</tr>
<tr>
<td>Parker</td>
<td>Average Depth</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>Parker</td>
<td>Gradient</td>
<td>2</td>
<td>0.05</td>
</tr>
<tr>
<td>Parker</td>
<td>Wetted Width</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>Parker</td>
<td>Bankfull Width</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>Edler</td>
<td>Wetted Width</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>Edler</td>
<td>Bankfull Width</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>Terrace Heights</td>
<td>Canopy Cover</td>
<td>2</td>
<td>0.05</td>
</tr>
<tr>
<td>Terrace Heights</td>
<td>Wetted Width</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>Terrace Heights</td>
<td>Bankfull Width</td>
<td>1</td>
<td>0.04</td>
</tr>
<tr>
<td>Gladmar</td>
<td>Canopy Cover</td>
<td>0</td>
<td>0.01</td>
</tr>
<tr>
<td>Gladmar</td>
<td>Wetted Width</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>Gladmar</td>
<td>Bankfull Width</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>Hanson</td>
<td>Average Velocity</td>
<td>1</td>
<td>0.04</td>
</tr>
</tbody>
</table>

There were mixed biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Tables 10-11). The Cluster dendrogram, however, indicates that the reaches do have a different macroinvertebrate community composition (Figure 1). The CCA plot also shows a
separation of macroinvertebrate community composition between the two reaches (Figure 5). Differences in cobble and gravel composition appeared to be the most explanatory physicochemical variables, in terms of site biological differences (Table 12).

Table 10. Mann-Whitney U tests of significant differences (p<0.05) of metric expressions between reaches above and below gravel pit ponds. Each metric decreases with human disturbance. Grey boxes represent significantly larger values in the contral reaches, and yellow boxes represent significantly lower values in the control reaches (i.e. grey boxes indicate the control reach has a "better" rank score).

<table>
<thead>
<tr>
<th>No.</th>
<th>Taxa</th>
<th>No. Intol</th>
<th>No. Cling</th>
<th>No. Ephem</th>
<th>No. Plecop</th>
<th>No. Trichop</th>
<th>No. EPT</th>
<th>No. LL</th>
<th>% Cling</th>
<th>% Ephem</th>
<th>% EPT</th>
<th>% Pred</th>
</tr>
</thead>
<tbody>
<tr>
<td>DeAtley</td>
<td>0.11</td>
<td>0.32</td>
<td>0.03</td>
<td>0.02</td>
<td>1.00</td>
<td>0.02</td>
<td>0.02</td>
<td>0.04</td>
<td>0.02</td>
<td>0.02</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
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<td>0.08</td>
<td>1.00</td>
<td>0.02</td>
<td>0.02</td>
<td>0.13</td>
<td>0.02</td>
<td>0.02</td>
<td>0.77</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.15</td>
</tr>
<tr>
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<td>0.02</td>
<td>0.19</td>
<td>0.02</td>
<td>0.88</td>
<td>0.06</td>
<td>0.04</td>
<td>0.15</td>
<td>0.04</td>
<td>0.15</td>
<td>0.02</td>
</tr>
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<td>0.04</td>
<td>0.66</td>
<td>0.02</td>
<td>1.00</td>
<td>0.47</td>
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<td>0.02</td>
<td>0.04</td>
<td>0.08</td>
<td>0.04</td>
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<tr>
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<td>0.54</td>
<td>0.76</td>
<td>0.10</td>
<td>0.66</td>
<td>0.18</td>
<td>0.19</td>
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<td>0.56</td>
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</tr>
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<td>0.04</td>
<td>0.13</td>
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<td>0.14</td>
<td>0.28</td>
<td>0.25</td>
<td>0.08</td>
<td>0.56</td>
<td>0.25</td>
</tr>
<tr>
<td>I-90 Pond 4</td>
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<td>0.32</td>
<td>0.11</td>
<td>0.55</td>
<td>0.76</td>
<td>0.55</td>
<td>0.77</td>
<td>0.04</td>
<td>0.77</td>
<td>0.56</td>
<td>0.77</td>
<td>1.00</td>
</tr>
<tr>
<td>Gladmar</td>
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<td>0.19</td>
<td>0.65</td>
<td>0.06</td>
<td>0.02</td>
<td>0.18</td>
<td>0.18</td>
<td>0.46</td>
<td>0.04</td>
<td>0.39</td>
<td>0.77</td>
<td>0.77</td>
</tr>
<tr>
<td>Hanson</td>
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<td>0.10</td>
<td>0.19</td>
<td>0.77</td>
<td>0.11</td>
<td>0.24</td>
<td>0.56</td>
<td>0.76</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
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</tr>
<tr>
<td>All Sites</td>
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<td>0.01</td>
<td>0.02</td>
<td>0.42</td>
<td>0.45</td>
<td>0.16</td>
<td>0.08</td>
<td>0.98</td>
<td>0.68</td>
<td>0.63</td>
<td>0.58</td>
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</tbody>
</table>

Table 11. Mann-Whitney U tests of significant differences (p<0.05) of metric expressions between reaches above and below gravel pit ponds. Each metric increases with human disturbance. Grey boxes represent significantly larger values in the contral reaches, and yellow boxes represent significantly lower values in the control reaches (i.e. grey boxes indicate the control reach has a "better" rank score).

<table>
<thead>
<tr>
<th>HBI</th>
<th>% Tol</th>
<th>% Chiro</th>
<th>% Filt</th>
<th>% Scrap</th>
<th>% Top 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DeAtley</td>
<td>0.04</td>
<td>0.15</td>
<td>0.02</td>
<td>0.02</td>
<td>1.00</td>
</tr>
<tr>
<td>I-82 Pond 5</td>
<td>0.02</td>
<td>0.25</td>
<td>1.00</td>
<td>0.01</td>
<td>0.39</td>
</tr>
<tr>
<td>Parker</td>
<td>0.25</td>
<td>0.77</td>
<td>1.00</td>
<td>0.56</td>
<td>0.25</td>
</tr>
<tr>
<td>Edler</td>
<td>0.77</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.56</td>
</tr>
<tr>
<td>Newland</td>
<td>0.15</td>
<td>0.77</td>
<td>0.25</td>
<td>1.00</td>
<td>0.15</td>
</tr>
<tr>
<td>Terrace Heights</td>
<td>0.77</td>
<td>0.02</td>
<td>0.08</td>
<td>0.25</td>
<td>0.02</td>
</tr>
<tr>
<td>I-90 Pond 4</td>
<td>0.77</td>
<td>0.56</td>
<td>0.77</td>
<td>0.39</td>
<td>1.00</td>
</tr>
<tr>
<td>Gladmar</td>
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<td>0.15</td>
<td>0.25</td>
<td>0.08</td>
<td>0.15</td>
</tr>
<tr>
<td>Hanson</td>
<td>0.02</td>
<td>0.15</td>
<td>0.02</td>
<td>0.56</td>
<td>0.02</td>
</tr>
<tr>
<td>All Sites</td>
<td>0.65</td>
<td>0.68</td>
<td>0.94</td>
<td>0.32</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Figure 5. Canonical Correspondence bi-plot with Hanson benthic macroinvertebrae site distribution and major physicochemical explanatory vectors. The prefix “l_” indicates a site downstream from the gravel pit. The prefix “u_” indicates a site upstream from the gravel pit.
Table 12. Canonical correlations of physicochemical variables to ordination axes at the Hanson river sites.

<table>
<thead>
<tr>
<th></th>
<th>Axis 1 (x-axis)</th>
<th>Axis 2 (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetted Width</td>
<td>.05</td>
<td>n.s.</td>
</tr>
<tr>
<td>Average Depth</td>
<td>-.02</td>
<td>n.s.</td>
</tr>
<tr>
<td>Average Velocity</td>
<td>-.32</td>
<td>n.s.</td>
</tr>
<tr>
<td>Gradient</td>
<td>-.23</td>
<td>n.s.</td>
</tr>
<tr>
<td>Cobble</td>
<td>.78</td>
<td>n.s.</td>
</tr>
<tr>
<td>Gravel</td>
<td>-.77</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

* n.s. = not significant at P<0.05

**Site 2: Gladmar**

Water quality exiting the Gladmar pond was good (Table 7). The Benthic macroinvertebrate community in the pond appeared to be in a condition more similar to the mainstem Yakima River than to isolated ponds (Table 3, 10-11).

In the river, water quality was similar between the upper and lower reach (Table 8). At the macroinvertebrate sampling locations, the upper reach had significantly wider wetted and bankfull widths (Figure 9), and the lower reach had significantly more canopy cover (Table 9).

There were mixed biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Tables 10-11). The Cluster dendrogram, however, indicates that the reaches did have a relatively different biological composition (Figure 1). The CCA plot also shows a slight separation of macroinvertebrate community composition between the two reaches (Figure 6). Differences in wetted width appeared to be the most explanatory physicochemical variable, in terms of site biological differences (Table 13).
Figure 6. Canonical Correspondence bi-plot with Gladmar benthic macroinvertebrae site distribution and major physicochemical explanatory vectors. The prefix “l_” indicates a site downstream from the gravel pit. The prefix “u_” indicates a site upstream from the gravel pit.
Table 13. Cononical correlations of physicochemical variables to ordination axes at the Gladmar river sites.

<table>
<thead>
<tr>
<th></th>
<th>Axis 1 (x-axis)</th>
<th>Axis 2 (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetted Width</td>
<td>0.86</td>
<td>.35</td>
</tr>
<tr>
<td>Average Depth</td>
<td>n.s.</td>
<td>.81</td>
</tr>
<tr>
<td>Average Velocity</td>
<td>0.25</td>
<td>.07</td>
</tr>
<tr>
<td>Gradient</td>
<td>n.s.</td>
<td>.20</td>
</tr>
<tr>
<td>Cobble</td>
<td>n.s.</td>
<td>.64</td>
</tr>
<tr>
<td>Gravel</td>
<td>n.s.</td>
<td>-.65</td>
</tr>
</tbody>
</table>

* n.s. = not significant at P<0.05

**Site 3: I-90 Pond 5**

I-90 Pond 5 had good water quality and was not stratified at the time of sampling (Table 7, Figure 3). The Benthic macroinvertebrate community appeared to be in a condition typical of this lentic habitat (Table 3).

In the river, water quality was similar between the upper and lower reach (Table 8). Channel morphology and sediment composition were also similar between reaches, with no statistical differences.

There was very little difference in biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Tables 10-11). The Cluster dendrogram, however, indicates that the reaches did have a relatively different biological composition (Figure 1). The CCA plot also shows a weak separation of macroinvertebrate community composition between the two reaches (Figure 7). Differences in average depth, wetted width, and gravel appeared to be the most important physicochemical variables, in terms of explaining site biological differences (Table 14).
Figure 7. Canonical Correspondence bi-plot with I-90 Pond 4 benthic macroinvertebrae site distribution and major physicochemical explanatory vectors. The prefix “l_” indicates a site downstream from the gravel pit. The prefix “u_” indicates a site upstream from the gravel pit.
Table 14. Canonical correlations of physicochemical variables to ordination axes at the I-90 Pond 4 river sites.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Axis 1 (x-axis)</th>
<th>Axis 2 (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetted Width</td>
<td>.27</td>
<td>.19</td>
</tr>
<tr>
<td>Average Depth</td>
<td>-.52</td>
<td>-.06</td>
</tr>
<tr>
<td>Average Velocity</td>
<td>n.s.</td>
<td>.50</td>
</tr>
<tr>
<td>Gradient</td>
<td>n.s.</td>
<td>.35</td>
</tr>
<tr>
<td>Cobble</td>
<td>n.s.</td>
<td>.15</td>
</tr>
<tr>
<td>Gravel</td>
<td>.22</td>
<td>.17</td>
</tr>
</tbody>
</table>

* n.s. = not significant at P<0.05

Site 4: Selah Ponds

The Selah Pond had marginal water quality and was stratified at the time of sampling (Table 7, Figure 3). There were low dissolved oxygen conditions at the bottom of the pond, and the surface was relatively alkaline. The Benthic macroinvertebrate community in the pond had relatively few taxa, and was dominated numerically by a subset of those taxa (Table 3).

In the river, water quality was similar between the upper and lower reach (Table 8). Channel morphology and sediment composition were also similar between reaches, with no statistical differences.

There was very little difference in biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Tables 10-11). The Cluster dendrogram did not show a difference between reach samples either (Figure 1). The CCA plot also shows a slight separation of macroinvertebrate community composition between the two reaches (Figure 8). Out of the physicochemical variables that were correlated with the CCA axes, only gradient could be interpreted as having a relationship with site distribution (Table 15).
Figure 8. Canonical Correspondence bi-plot with the Selah river benthic macroinvertebrae site distribution and major physicochemical explanatory vectors. The prefix “l_” indicates a site downstream from the gravel pit. The prefix “u_” indicates a site upstream from the gravel pit.
Table 15. Canonical correlations of physicochemical variables to ordination axes at the Selah river sites.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Axis 1 (x-axis)</th>
<th>Axis 2 (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetted Width</td>
<td>-.09</td>
<td>.75</td>
</tr>
<tr>
<td>Average Depth</td>
<td>n.s.</td>
<td>-.58</td>
</tr>
<tr>
<td>Average Velocity</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Gradient</td>
<td>.36</td>
<td>.77</td>
</tr>
<tr>
<td>Cobble</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Gravel</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

* n.s. = not significant at P<0.05

**Site 5: Terrace Heights**

The historic Terrace Heights pond is now a side channel. The side channel had water quality similar to the main channel (Table 7-8). The Benthic macroinvertebrate community in the pond appeared to be in a condition more similar to the mainstem Yakima River than to isolated ponds (Table 3, 10-11).

In the river, the lower reach was warmer, although it was sampled on a different day (Table 8). Other physicochemical differences between the reaches were canopy cover (more downstream), wetted width (larger downstream), and bankfull width (larger downstream).

There was very little difference in biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Tables 10-11). The Cluster dendrogram did not show a difference between reach samples either (Figure 1). The CCA plot also shows a slight separation of macroinvertebrate community composition between the two reaches (Figure 9). The Average depth and wetted width appeared to be related to the slight divergence in biological condition between reaches (Table 16).
Figure 9. Canonical Correspondence bi-plot with the Terrace Heights river benthic macroinvertebrate site distribution and major physicochemical explanatory vectors. The prefix “l_” indicates a site downstream from the gravel pit. The prefix “u_” indicates a site upstream from the gravel pit.
Table 16. Canonical correlations of physicochemical variables to ordination axes at the Terrace Heights river sites.

<table>
<thead>
<tr>
<th></th>
<th>Axis 1 (x-axis)</th>
<th>Axis 2 (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetted Width</td>
<td>.79</td>
<td>n.s.</td>
</tr>
<tr>
<td>Average Depth</td>
<td>.72</td>
<td>n.s.</td>
</tr>
<tr>
<td>Average Velocity</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Gradient</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Cobble</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Gravel</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

* n.s. = not significant at P<0.05

**Site 6: Newland Pond 1**

The Newland Pond had marginal water quality with high TDS and a low secchi depth. (Table 7). The Benthic macroinvertebrate community in the pond had relatively few taxa, and was dominated numerically by a subset of those taxa (Table 3).

In the river, the lower reach had less dissolved oxygen and was less alkaline as the upper reach (Table 8). Channel morphology and sediment composition were similar between reaches, with no statistical differences.

There were no statistical differences in biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Tables 10-11). The Cluster dendrogram did not show a strong difference between reach samples either (Figure 1). The CCA plot did not show a clear pattern of macroinvertebrate community composition between the two reaches (Figure 10).
Figure 10. Canonical Correspondence bi-plot with the Newland river benthic macroinvertebrate site distribution and major physicochemical explanatory vectors. The prefix “l_” indicates a site downstream from the gravel pit. The prefix “u_” indicates a site upstream from the gravel pit.
**Site 7: Edler Ponds**

Edler Pond 1 had poor water quality (Table 7). There were low dissolved oxygen conditions at the bottom of the pond, and the surface was relatively alkaline. Edler Pond 1 also had relatively high Ortho-Phosphorus, chlorophyll a, and TDS, and a low secchi depth. The Benthic macroinvertebrate community in the pond was dominated by minority of taxa, indicating disturbance (Table 3).

In the river, water quality was similar between the upper and lower reach (Table 8). The upper reach had a larger wetted and bankfull width than the lower reach.

There were mixed biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Tables 10-11). The Cluster dendrogram did not show a difference between reach samples either (Figure 1). The CCA plot also shows a slight separation of macroinvertebrate community composition between the two reaches (Figure 11). Out of the physicochemical variables that were correlated with the CCA axes, wetted width, gradient, and cobble could be interpreted as having a relationship with site distribution (Table 17).
Figure 11. Canonical Correspondence bi-plot with the Edler river benthic macroinvertebrate site distribution and major physicochemical explanatory vectors. The prefix "l_" indicates a site downstream from the gravel pit. The prefix "u_" indicates a site upstream from the gravel pit.
### Table 17. Canonical correlations of physicochemical variables to ordination axes at the Edler river sites.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Axis 1 (x-axis)</th>
<th>Axis 2 (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetted Width</td>
<td>.99</td>
<td>n.s.</td>
</tr>
<tr>
<td>Average Depth</td>
<td>n.s.</td>
<td>.07</td>
</tr>
<tr>
<td>Average Velocity</td>
<td>n.s.</td>
<td>.25</td>
</tr>
<tr>
<td>Gradient</td>
<td>.35</td>
<td>-.22</td>
</tr>
<tr>
<td>Cobble</td>
<td>.67</td>
<td>-.31</td>
</tr>
<tr>
<td>Gravel</td>
<td>n.s.</td>
<td>.42</td>
</tr>
</tbody>
</table>

* n.s. = not significant at P<0.05

**Site 8: Parker**

The Parker ponds had marginal water quality at its outlet, and was similar to the adjacent mainstem (Table 7-8). The Benthic macroinvertebrate community in the pond had a taxa richness similar to that of other isolated ponds, and was dominated numerically by a subset of those taxa (Table 3).

In the river, water quality was similar between the upper and lower reach (Table 8). There were differences between the reaches with wetted and bankfull widths (greater in the lower), gradient (greater in the upper), and average depth (greater in the upper).

The biometric results indicate that upper (control) reach was in a better biological condition than the lower reach (Tables 10-11). The Cluster dendrogram also showed a difference between reaches (Figure 1). The CCA plot also showed a slight separation of macroinvertebrate community composition between the two reaches (Figure 12). Out of the physicochemical variables that were correlated with the CCA axes, wetted width, cobble, and gravel could be interpreted as having a relationship with site distribution (Table 18).
Figure 12. Canonical Correspondence bi-plot with the Parker river benthic macroinvertebrate site distribution and major physicochemical explanatory vectors. The prefix “l_” indicates a site downstream from the gravel pit. The prefix “u_” indicates a site upstream from the gravel pit.
Table 18. Canonical correlations of physicochemical variables to ordination axes at the Parker river sites.

<table>
<thead>
<tr>
<th></th>
<th>Axis 1 (x-axis)</th>
<th>Axis 2 (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetted Width</td>
<td>-.88</td>
<td>-.35</td>
</tr>
<tr>
<td>Average Depth</td>
<td>n.s.</td>
<td>-.41</td>
</tr>
<tr>
<td>Average Velocity</td>
<td>n.s.</td>
<td>-.53</td>
</tr>
<tr>
<td>Gradient</td>
<td>n.s.</td>
<td>-.21</td>
</tr>
<tr>
<td>Cobble</td>
<td>.62</td>
<td>.53</td>
</tr>
<tr>
<td>Gravel</td>
<td>-.59</td>
<td>-.55</td>
</tr>
</tbody>
</table>

* n.s. = not significant at P<0.05

Site 9: I-82 Ponds 4

The I-82 Pond 4 had marginal water quality with low dissolved oxygen at the bottom of the pond (Table 7, Figure 3). The Benthic macroinvertebrate community in the pond had relatively few taxa. Out of those few taxa, many were tolerant (Table 3).

In the river, the water quality in the lower reach had much lower dissolved oxygen and less alkaline pH than in the upper reach (Table 8). These conditions in the lower reach resembled the water quality at the bottom of pond 4. Canopy cover was greater in the lower reach (Table 9).

The biometric results indicate that upper (control) reach was in a better biological condition than the lower reach (Tables 10-11). The Cluster dendrogram did not show a clear difference in species similarity (Figure 1). The CCA plot showed a slight separation of macroinvertebrate community composition between the two reaches (Figure 13). Out of the physicochemical variables that were correlated with the CCA axes, wetted width, average velocity, and gradient could be interpreted as having a relationship with site distribution (Table 19).
Figure 13. Canonical Correspondence bi-plot with the I-82 Pond 4 river benthic macroinvertebrate site distribution and major physicochemical explanatory vectors. The prefix “l_” indicates a site downstream from the gravel pit. The prefix “u_” indicates a site upstream from the gravel pit.
### Table 19. Cononical correlations of physicochemical variables to ordination axes at the I-82 Pond 5 river sites.

<table>
<thead>
<tr>
<th></th>
<th>Axis 1 (x-axis)</th>
<th>Axis 2 (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetted Width</td>
<td>0.63</td>
<td>0.15</td>
</tr>
<tr>
<td>Average Depth</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Average Velocity</td>
<td>0.63</td>
<td>n.s.</td>
</tr>
<tr>
<td>Gradient</td>
<td>-0.88</td>
<td>n.s.</td>
</tr>
<tr>
<td>Cobble</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Gravel</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

* n.s. = not significant at P<0.05

### Site 10: DeAtley Pit

The DeAtley Pit had poor water quality and was stratified at the time of sampling (Table 7, Figure 3). There were low dissolved oxygen conditions at the bottom of the pond, and supersaturated, alkaline conditions near the surface. The DeAtley pit also had a relatively high chlorophyll a and TDS concentration, resulting in a low secchi depth value. The Benthic macroinvertebrate community in the pond had a relatively average amount of taxa, although there were an above average number of tolerant taxa, resulting in a low HBI score (Table 3).

In the river, water quality was similar between the upper and lower reach (Table 8). There were differences between the reaches with wetted and bankfull widths (greater in the lower), gradient (greater in the upper), and average velocity (greater in the upper).

The biometric results indicate that upper (control) reach was in a better biological condition than the lower reach (Tables 10-11). The Cluster dendrogram also showed a difference in species similarity (Figure 1). The CCA plot showed a slight separation of macroinvertebrate community composition between the two reaches (Figure 13). Out of the physicochemical variables that were correlated with the CCA axes, wetted width, average velocity, and gradient appeared to account for site distribution, even though they were not significantly correlated with axis 1 (Figure 13, Table 19).
Figure 14. Canonical Correspondence bi-plot with the DeAtley river benthic macroinvertebrate site distribution and major physicochemical explanatory vectors. The prefix “l_” indicates a site downstream from the gravel pit. The prefix “u_” indicates a site upstream from the gravel pit.
Table 20. Canonical correlations of physicochemical variables to ordination axes at the DeAtley river sites.

<table>
<thead>
<tr>
<th></th>
<th>Axis 1 (x-axis)</th>
<th>Axis 2 (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetted Width</td>
<td>n.s.</td>
<td>-0.02</td>
</tr>
<tr>
<td>Average Depth</td>
<td>n.s.</td>
<td>-0.23</td>
</tr>
<tr>
<td>Average Velocity</td>
<td>n.s.</td>
<td>0.01</td>
</tr>
<tr>
<td>Gradient</td>
<td>n.s.</td>
<td>-0.02</td>
</tr>
<tr>
<td>Cobble</td>
<td>n.s.</td>
<td>-0.64</td>
</tr>
<tr>
<td>Gravel</td>
<td>n.s.</td>
<td>0.56</td>
</tr>
</tbody>
</table>

* n.s. = not significant at P<0.05

**Discussion**

DeAtley, Edler, and Selah Ponds appeared to be the most eutrophic. The poor water quality in DeAtley and Edler coincided with cyanobacteria blooms and relative paucity of submersed macrophytes. Further investigation of pond benthic invertebrate distribution may support these results. These results should also be compared to pond morphology, sediment distribution, temperature, and fish distribution. Among the three avulsed sites, Gladmar and Terrace Heights had physicochemical and biological attributes similar to side channels, while Parker retained attributes more similar to the isolated ponds. Pit morphology, sediment distribution, and fish distribution, along with these data, could give us a clearer picture of what avulsion scenario will produce the highest quality riverine habitat.

River water quality and benthic macroinvertebrate distribution were strongly correlated with elevation and river mile. Even though elevation and river mile have a perfect rank correlation by definition, the two variables have different ecological meaning. Elevation is a component of natural variability and river mile accounts for largely anthropogenic variability. Cluster analysis results indicated that river benthic macroinvertebrates varied longitudinally along the river (i.e. river mile and/or elevation).

The macroinvertebrates also clustered strongly on site (i.e. above or below the pit), nesting in the overarching trend of longitudinal variability. Site clustering strongly suggests that some difference(s) in local setting was contributing to biological variation. When CCA was run with all 20 river sites (80 samples), those same overarching variables, river mile and elevation, were the most correlated to site distribution, with channel width and water velocity also being important. The cluster analysis indicated that many of the lower reaches had different biological community compositions relative to their upstream (above) controls.

The question is, what physicochemical variable(s) are responsible for the differences? All reach pairs, except Newland, had at least a slight clustering of samples by reach in the CCA plots. Since the clustering was so slight, the variability could have been due to differences in stream setting. Alternatively, we could also expect differences due to the presence of an avulsed pit in-between the reaches to occur. Gladmar and Terrace Heights had mixed biometric results, while Parker clearly had a higher quality biological...
condition above the avulsed pond. Finally, the impacts of future actions with these ponds, such as avulsing currently disconnected ponds, or further reclamation of new ponds, can be investigated by comparing the macroinvertebrate community condition with the samples collected for this survey.

LITERATURE CITED


Arbor Science. 175-235.


Yakima County Planning Department 2002. Floodplain Mining Study Quality Assurance Project Plan.