# Appendix F

## Columbia Performance Measure Information Sheets

| PM Info Sheet # | Location | Topic |
|---|---|---|
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| 2 | Kinbasket Reservoir | Recreation |
| 3 | Kinbasket Reservoir | Heritage and Culture |
| 4 | Kinbasket Reservoir | Erosion |
| 5 | Kinbasket Reservoir | Vegetation |
| 6 | Kinbasket Reservoir | Dust Potential |
| 7 | Kinbasket Reservoir | Pelagic Productivity |
| 10 | Mid-Columbia River | Recreation |
| 11 | Mid-Columbia River | Vegetation |
| 12 | Mid-Columbia River | Fish Habitat |
| 13 | Mid-Columbia River | Wildlife |
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| 16 | Arrow Lakes Reservoir | Recreation |
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# PERFORMANCE MEASURE INFORMATION SHEET #1

## KINBASKET RESERVOIR: NAVIGATION

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Navigation/Kinbasket Reservoir | Navigability | # days per year | Reports # of days per year that a site is navigable to commercial operators | 7 days per year |

## Description

Commercial operations (primarily local forest companies surrounding Kinbasket Reservoir) can be affected by reservoir elevations. Either low or high reservoir elevations can result in a disruption to operations. When reservoir levels do not fall within critical elevations, forest companies respond by changing sites or routes, altering facilities or equipment and/or by delaying logging or transport operations, all of which increase costs. One of the primary regions of concern related to navigation is Kinbasket Reservoir because of its use by local forest companies and its extensive drawdown zone.

## Performance Measures

To determine appropriate performance measures, a preliminary list of sites in Kinbasket Reservoir potentially affected by BC Hydro's operations was identified by the Navigation/Transportation WUP Technical Subcommittee. The critical elevations at which disruption to navigation occurs at each site were then defined. These critical elevations were subsequently reviewed by participants of the NTS Stakeholder Forum meeting in October 2010. Revisions/updates were made to the sites and critical elevations, and specific time periods were defined for each site. These are summarized below.

| Site | Critical Elevation (ft) | Critical Time period | Commercial Operator |
|---|---|---|---|
| Harvey Creek | 2415 ft and above | 30 June - 31 Oct | Bell Pole Timber & Balchaen Consolidated Contracting |
| Schlichting Creek* | 2400 ft and above | 1 May – 30 Nov | Sterling Lumber |
| Downie Timber | 2360 ft and above | Year-round | Wood River Forest Products |

* Schlichting Creek is a BC Forest Service site used by commercial operators on the reservoir. It replaces the Bush Harbour site.

## Calculations

For each scenario:

1. Assemble the simulated results for month-end reservoir elevations over 60 years (1940-2000; Figure 1).
2. Count the number of days over each year that the reservoir water levels are at or above the critical elevation for each site.
3. Summarize all statistics (Figures 2-4).

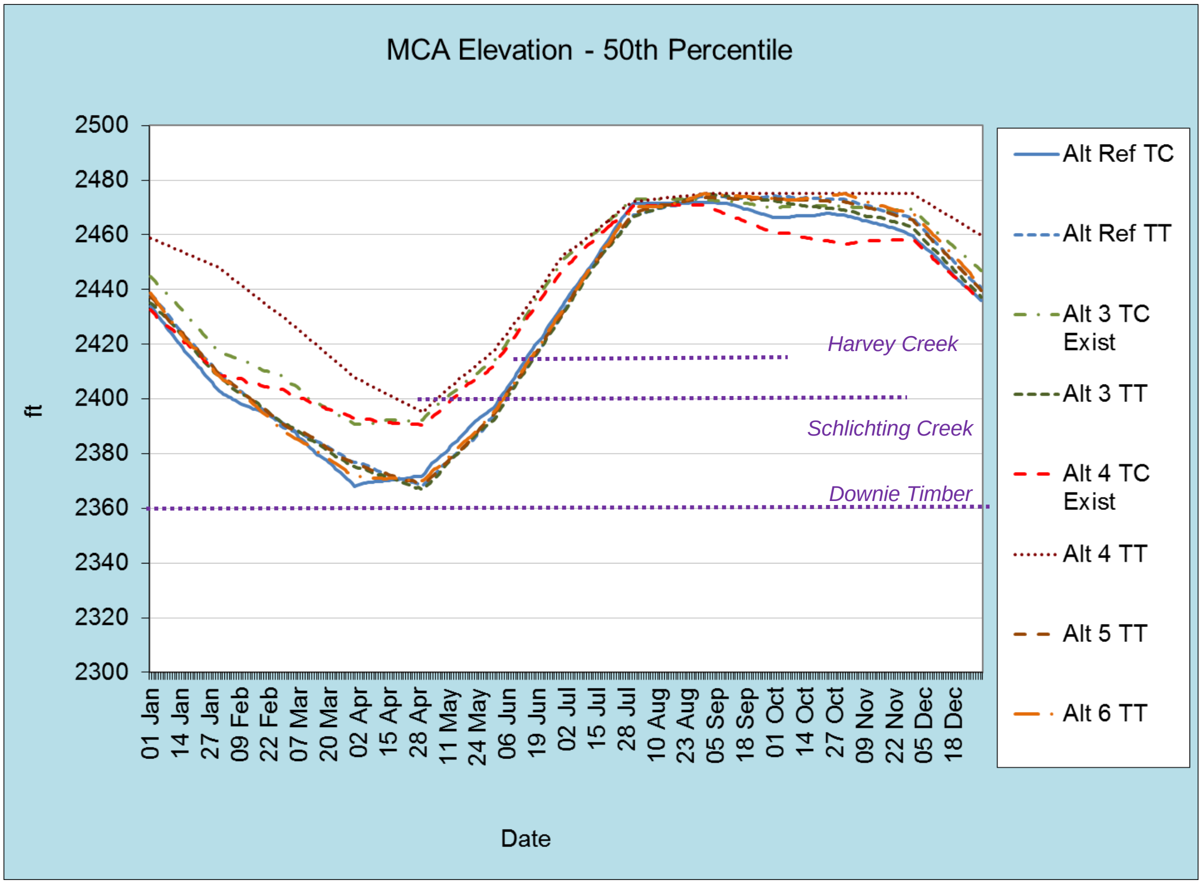



**Figure 1. HYSIM Simulated Kinbasket Reservoir elevations. Median over 60 years showing the preferred elevation ranges for navigation**

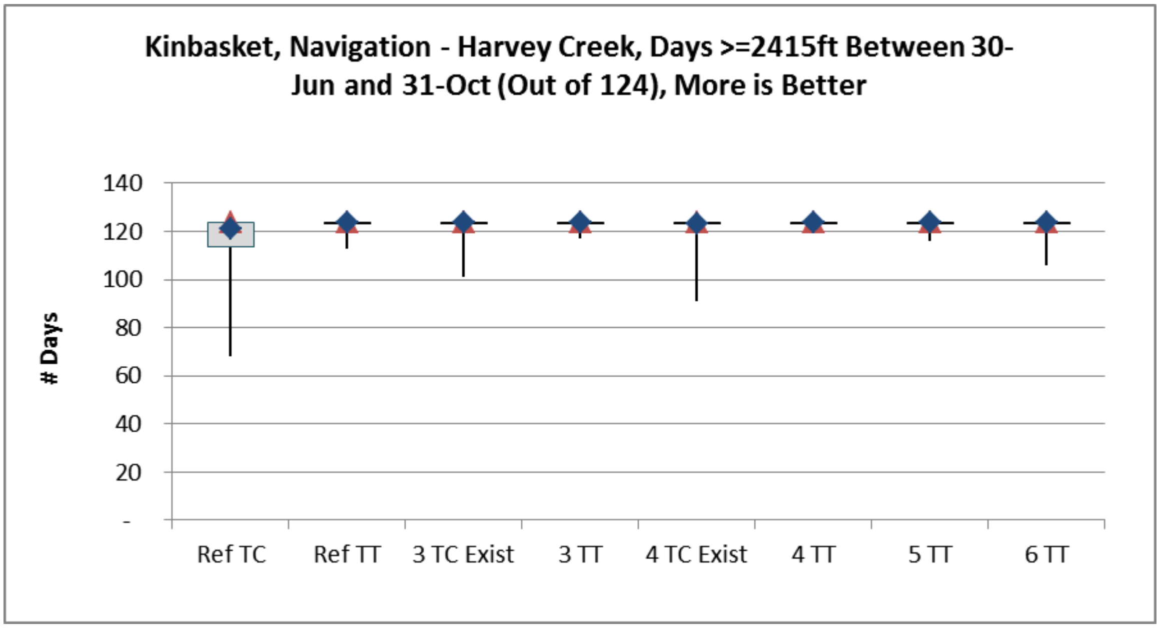
## Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1940 – 2000).
- Assumes that the critical elevations for each site are accurate

## Results

### Harvey Creek

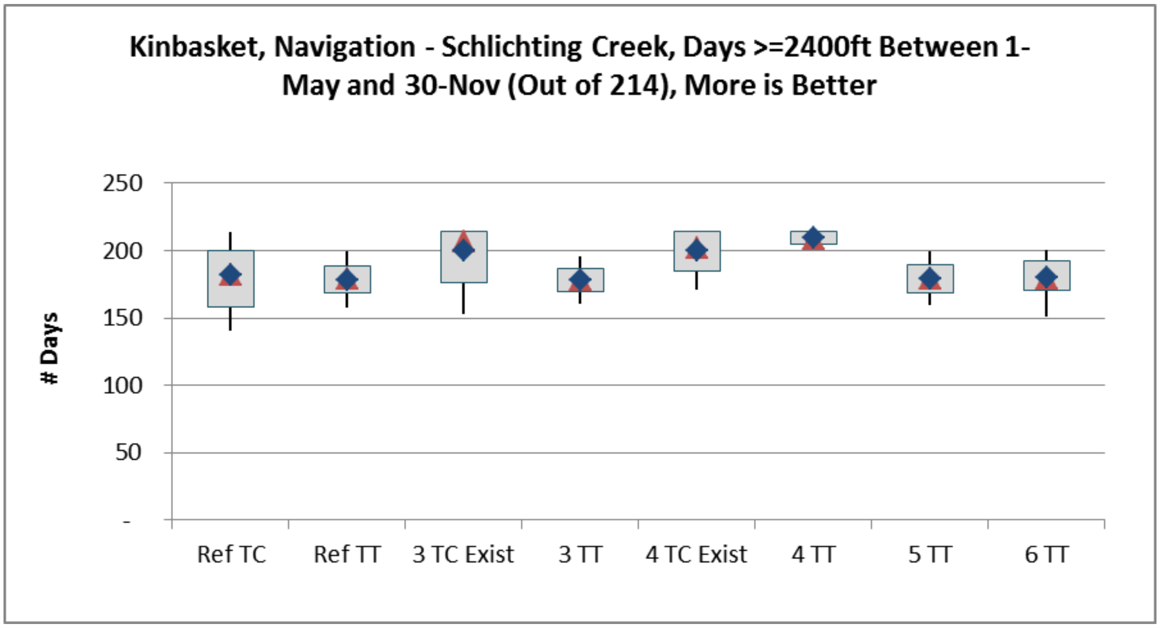
**Figure 2. Navigable Days at Harvey Creek**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | Max |
| 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 90th |
| 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | Med |
| 121 | 124 | 124 | 124 | 123 | 124 | 124 | 124 | Mean |
| 114 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 10th |
| 68 | 113 | 101 | 117 | 91 | 124 | 116 | 106 | Min |

## Schlichting Creek

**Figure 3. Navigable Days at Schlichting Creek – HYSIM Results**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 214 | 200 | 214 | 196 | 214 | 214 | 200 | 201 | Max |
| 200 | 189 | 214 | 187 | 214 | 214 | 189 | 192 | 90th |
| 182 | 179 | 207 | 178 | 202 | 209 | 179 | 179 | Med |
| 182 | 178 | 200 | 178 | 200 | 209 | 179 | 180 | Mean |
| 158 | 169 | 176 | 170 | 185 | 205 | 169 | 171 | 10th |
| 141 | 158 | 153 | 161 | 171 | 202 | 160 | 151 | Min |

## Downie Timber

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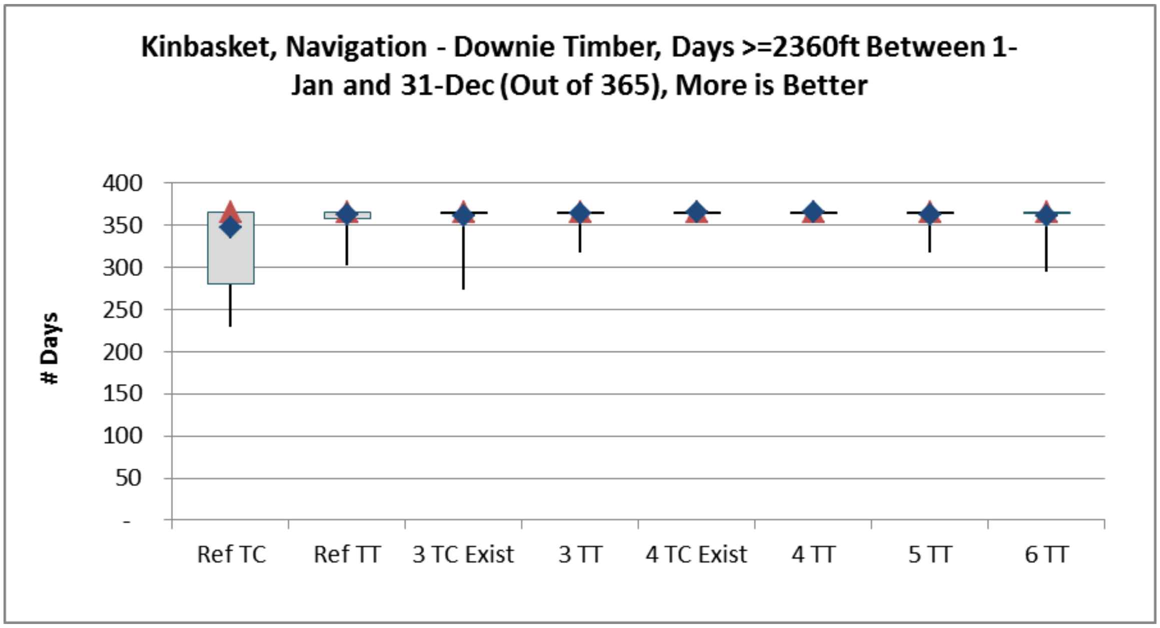
**Figure 4. Navigable Days at Downie Timber – HYSIM Results.** Red-shaded results carried forward into Consequence Table.




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 365 | 365 | 365 | 365 | 365 | 365 | 365 | 365 | Max |
| 365 | 365 | 365 | 365 | 365 | 365 | 365 | 365 | 90th |
| 365 | 365 | 365 | 365 | 365 | 365 | 365 | 365 | Med |
| 348 | 362 | 361 | 364 | 365 | 365 | 363 | 361 | Mean |
| 281 | 358 | 365 | 365 | 365 | 365 | 365 | 364 | 10th |
| 229 | 302 | 274 | 318 | 365 | 365 | 318 | 295 | Min |

# PERFORMANCE MEASURE INFORMATION SHEET # 2

## KINBASKET RESERVOIR: RECREATION

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Recreation/Kinbasket Reservoir | Access Days | # access days by activity by region | Sum of # days reservoir elevations are within the preferred ranges for shore-based and water-based activities | 7 days |

## Description

Kinbasket Reservoir is considered to have high wilderness and scenic values, and supports a number of key sportfish species (bull trout, rainbow trout, kokanee). Fishing is the main recreational activity on the reservoir, with the majority of fishing activity occurring within about 15 km of launch points due, in part, to navigational concerns on the reservoir. Other activities include wildlife viewing, camping, picnicking, outfitting, cottage use, hiking and nature study. Although winter use of the reservoir is light, snowmobiling, ice fishing and ice sailing activity is increasing. While issues such as debris accumulation are being addressed by BC Hydro through a large-scale debris removal program, reservoir water levels continue to be a concern to local users. A new ramp at Bush Harbour was recently constructed by BC Hydro as part of its Water License Requirements Program.

Recreation access and associated benefits are important in Kinbasket Reservoir. Local communities benefit from improvements to the quality and diversity of recreation and tourism experiences through a greater quality of life, as well as through local economic development benefits that result from increased usage. A number of key factors that affect recreational quality and use include:

- Diversity and abundance of fish and wildlife, since many recreational activities are focused on enjoyment of these natural resources
- Ability to safely access the water or shorelines for water-based and shore-based activities
- Visual quality of viewscapes (appearance of the reservoir related to avoidance of exposed mudflats/dust and exposed standing debris)
- Avoidance of navigational hazards

During the Columbia WUP process, it was agreed that boat access and shoreline access would capture most recreational interests. For boat access, the Recreation Technical Subcommittee identified preferred elevations over the recreation season that would provide "good opportunity" for a broad range of interests, including access via boat ramps, usability of boat ramps and quality of boating within that range of elevations. The boat access measure was not tied directly to physical structures (i.e., boat ramps). The shoreline access measure was defined around a range of elevations that constituted "good opportunity" for shore-based activities, with activities decreasing in frequency when the water is above or below this elevational zone. Again, this measure was not tied to site-specific elevation issues. The elevation zones were developed based on critical water levels for viewshed quality, shore-based activities and water-based activities, as summarized in RL&L (2001).

## Performance Measures

During the NTSA process, preferences for reservoir water levels and seasons of use for recreational activities were modified based on input from Kinbasket community members. The definitions for the performance measures were changed to better reflect the nature of key recreational activities in the Canoe and Columbia reaches, which is driven largely by the natural topography of the north and south ends of Kinbasket Reservoir. The shoreline of the Canoe Reach is largely steep sided except in the more northern end, which limits the amount of shore-based recreation (K. Mortensen, pers. comm.). Activities focus primarily on hiking, camping and picnicking, and opportunities appears to be constrained more by availability of suitable flat terrain than reservoir water levels (K. Mortensen, pers. comm.). Recreation pursuits focuses primarily on water-based activities, which can occur as early as April and as late as end of October depending on weather conditions in any given year. The preferred elevation range is driven largely by what's “good” for boating quality, fishing, viewshed quality and boat access to the reservoir.

In the Columbia Reach, low reservoir water levels can cause much of the reach to be essentially dry for at least three months of the year, primarily during the spring and early summer. At higher water levels, the area offers a broad range of both water-based and shore-based recreational opportunities. Boat-based activities can extend from early May (e.g., bear hunting) through to snow fall (e.g., burbot fishing) (R. Priest, pers. comm.). For shoreline activities, there is a preference for reservoir water levels to remain below full pool to minimize re-floating of debris that remains stranded at the higher elevations and provide for more desirable areas for shore activities (R. Priest, pers. comm.).

**PM Definitions**

| Area | Measure | Dates | Critical Elevation Zone |
|---|---|---|---|
| Canoe Reach | Water-based recreational activity | 01 Apr to 31 Oct | # days between 2404 – 2475 ft |
| Columbia Reach | Water-based recreational activity | 01 May to 31 Oct | # days between 2375 – 2475 ft |
| | Shore-based recreational activity | 01 May to 30 Sept | # days between 2444 – 2473 ft |

## Calculations

For each scenario:

1. Assemble the simulated results for month-end reservoir elevations over 1929-1999; Figure 1).
2. Count the number of days over the defined recreation seasons each year that the reservoir water levels fall within the preferred elevation ranges for water-based and shore-based activities.
3. Summarize all statistics (Figures 2-4).

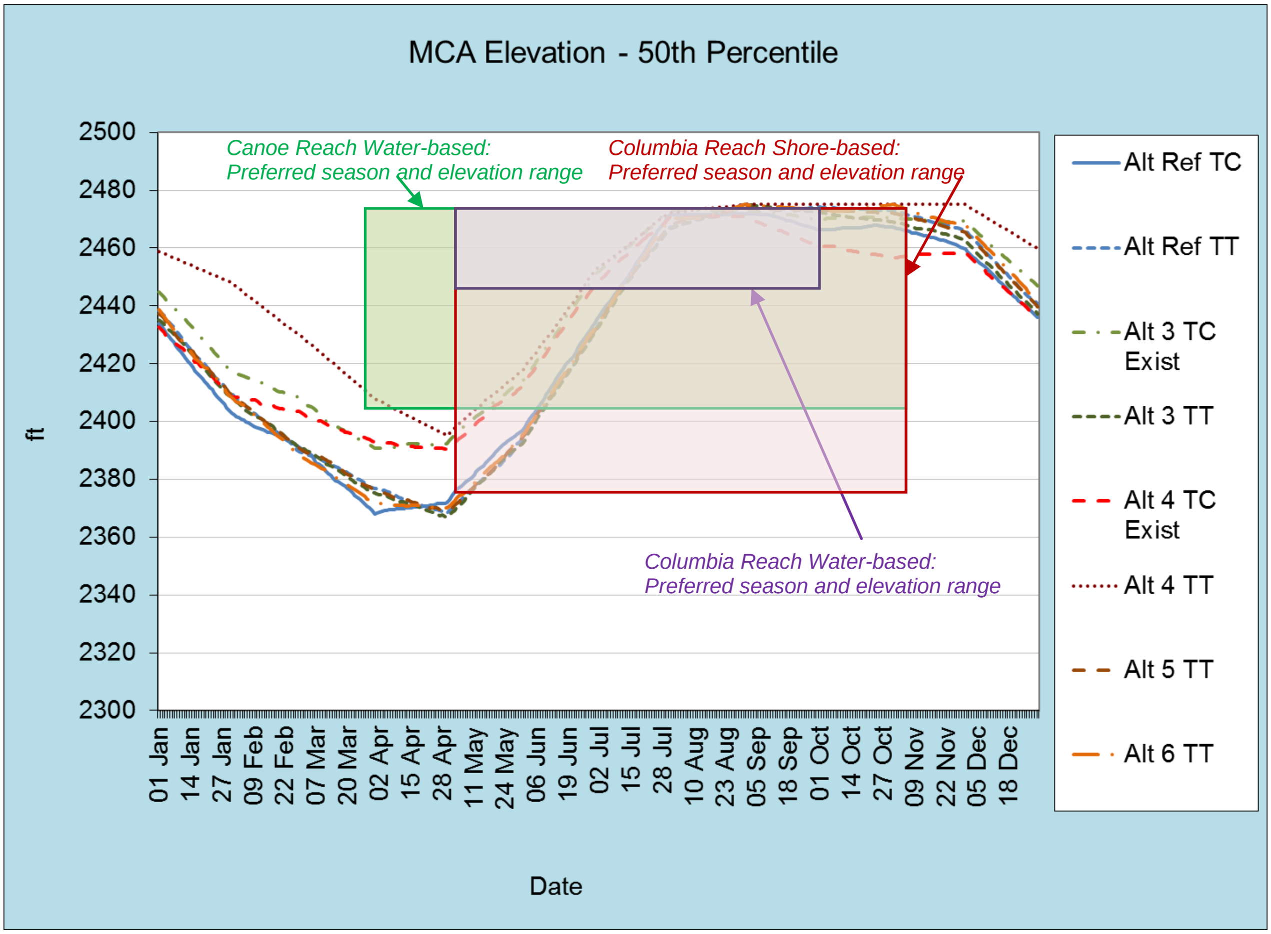



**Figure 1. Simulated Kinbasket Reservoir elevations. Median showing the preferred seasons and elevation ranges for recreation**

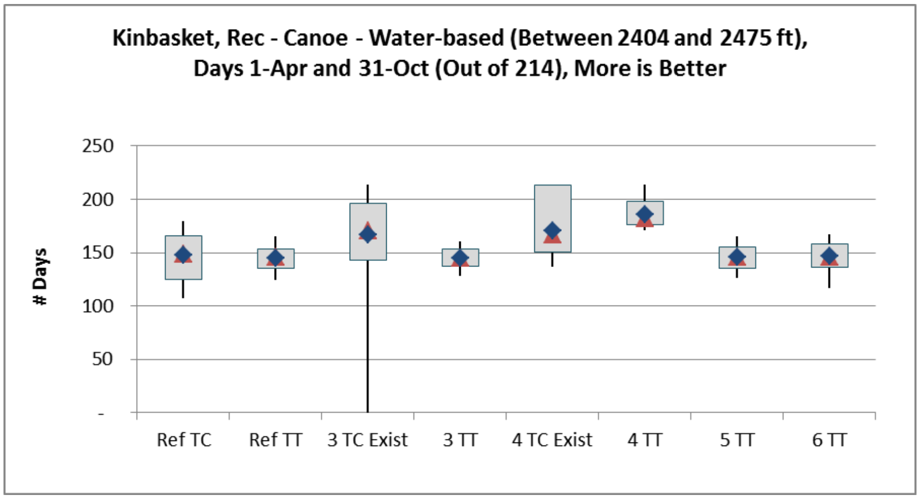
## Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1929 – 1999).
- Assumes that there is minimal recreational use outside the defined recreation season
- Assumes that the preferred season and elevations are accurate

## Results

### Canoe Reach

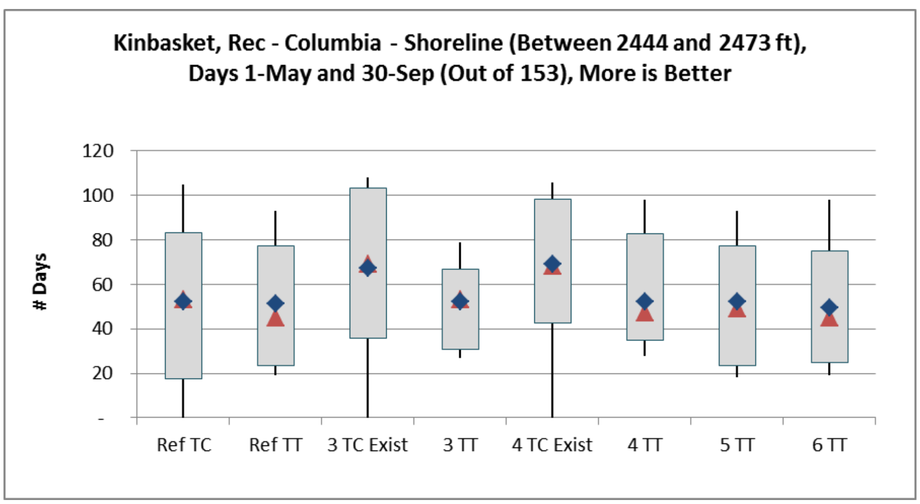
### Figure 2. Canoe Reach, Water-based Recreation Days –Results




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 180 | 165 | 214 | 161 | 214 | 214 | 165 | 167 | Max |
| 166 | 153 | 197 | 153 | 213 | 198 | 155 | 158 | 90th |
| 149 | 146 | 171 | 145 | 167 | 182 | 146 | 146 | Med |
| 148 | 145 | 166 | 145 | 170 | 185 | 146 | 146 | Mean |
| 125 | 136 | 143 | 137 | 151 | 176 | 136 | 137 | 10th |
| 107 | 124 | - | 128 | 137 | 171 | 126 | 117 | Min |

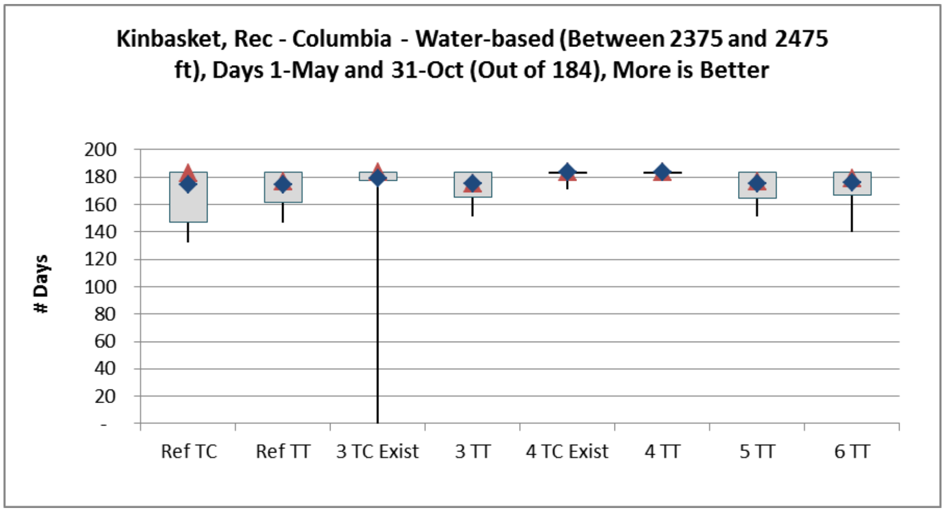
## Columbia Reach

### Figure 3. Columbia Reach, Water-based Recreation Days –Results




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 105 | 93 | 108 | 79 | 106 | 98 | 93 | 98 | Max |
| 83 | 77 | 103 | 67 | 98 | 83 | 77 | 75 | 90th |
| 53 | 45 | 69 | 53 | 68 | 47 | 49 | 45 | Med |
| 52 | 51 | 67 | 52 | 69 | 52 | 52 | 50 | Mean |
| 18 | 24 | 36 | 31 | 43 | 35 | 24 | 25 | 10th |
| - | 19 | - | 27 | - | 28 | 18 | 19 | Min |

**Figure 4. Columbia Reach, Shore-based Recreation Days –Results**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 184 | 184 | 184 | 184 | 184 | 184 | 184 | 184 | Max |
| 184 | 184 | 184 | 184 | 184 | 184 | 184 | 184 | 90th |
| 183 | 177 | 184 | 175 | 184 | 184 | 177 | 179 | Med |
| 175 | 175 | 179 | 175 | 184 | 184 | 176 | 176 | Mean |
| 147 | 162 | 178 | 166 | 184 | 184 | 165 | 167 | 10th |
| 132 | 147 | - | 151 | 171 | 184 | 151 | 140 | Min |

## References

RL&L Environmental Services Ltd. 2001. Water Use Plans – Environmental information review and data gap analysis. Volumes 1 & 2. Prepared for BC Hydro, Burnaby by RL&L Environmental Services in association with Robertson Environmental Services Ltd., Pandion Ecological Research Ltd., Bruce Haggerstone Landscape Architect, Pomeroy & Neil Consulting Ltd. and DVH Consulting. RL&L Report No. 858V1-F.

# PERFORMANCE MEASURE INFORMATION SHEET # 3

## KINBASKET RESERVOIR: CULTURE & HERITAGE

| Objective / Location | Performance Measure | Units | Description |
|---|---|---|---|
| Culture & Heritage / Kinbasket Reservoir | Archaeological sites – Wave Erosion | Weighted-Days reservoir is within sensitive elevation zones | Total number of weighted days that the reservoir is potentially eroding archaeological sites through wave action |
| | Archaeological sites – Full inundation | Weighted Days of full inundation | Total number of weighted days that the reservoir is potentially protecting archaeological sites by fully inundating them. |

## Description

The Columbia WUP Consultative Committee recognized the significance of heritage resources, particularly to the First Nations with an interest in the area. However, they were unable to fully evaluate the potential effects of operating alternatives on archaeological sites in Kinbasket Reservoir due to a lack of information on the number and condition of actively eroding archaeological sites in the reservoir. The contents and significance of documented sites within the reservoirs had not been comprehensively reviewed, and it is likely that additional undocumented archaeological sites exist in areas that have not been previously surveyed.

As part of WUP implementation, an archaeological overview was conducted on Kinbasket Reservoir in 2008 to identify and assess archaeological resource potential or sensitivity within portions of the drawdown zone with a primary focus on those areas with potential for revegetation. As part of this work, recommendations were also developed for subsequent archaeological work and possible mitigative options for identified potential conflicts with the WUP physical works programs. A total of 12 archaeological sites were identified in Kinbasket Reservoir during a survey of 13 vegetation polygons. Prior to this study, only one stone artifact had been documented in the vicinity of the reservoir. Consequently, these newly discovered archaeological deposits are considered to be highly significant from an archaeological perspective, as well as their value in better understanding the effects of reservoir operations on archaeological sites.

## Performance Measure

In developing a performance measure for the NTS analysis, an inventory of archaeological sites in the vicinity of Kinbasket Reservoir was obtained from the Remote Access to Archaeological Data (RAAD) database of the Archaeology Branch. The archaeology sites extracted from RAAD were selected based on their proximity to the Kinbasket shoreline as displayed in RAAD.

Elevations for each site were interpolated using a digital elevation model of Kinbasket Reservoir, which was collected between 2342 and 2483 ft. A 3-D terrain surface was generated from the digital elevation model, and the site polygons were draped over the terrain and the elevations were interpolated from the terrain surface heights. Some archaeology sites fell below or were beyond the DEM collection area, and were not included in the analysis. A total of 14 sites were found to exist within the lower limit of the DEM and full pool elevation of the reservoir.

The minimum and maximum site elevations were interpolated from the perimeter of the archaeology site. The results were manually inspected to ensure that significant peaks or depressions do not exist within the site boundaries that would alter the minimum or maximum value of the site.

The drawdown zone of Kinbasket Reservoir was divided into elevation bands between 2391 ft and 2476 ft. The total number of archaeological sites within each band was tallied corresponding to its minimum and maximum elevation. Each elevation band was weighted based on the number of sites inventoried in each band to provide a relative importance modifier.

**Table 1. Current Archaeological Site Inventory for Kinbasket Reservoir**

| | **Elevation Range (ft)** | | | |
|---|---|---|---|---|
| | **2391<band<2417** | **2417<band<2437** | **2437<band<2457** | **2457<band<2476** |
| Total sites within elevation band | 5 | 12 | 11 | 9 |
| Proportion of sites within band | 13.5% | 32.4% | 29.7% | 24.3% |
| Relative day weight | 0.42 | 1 | 0.92 | 0.75 |

There are multiple ways to consider the potential for operational impacts on archaeological sites. Two different approaches are presented here for consideration

**Performance Measure 1**
The method is based on concern over the potential for erosion of archaeological sites due to wave action. The number of days that the reservoir is within each elevation band over the year is weighted by the number of sites known to exist within each band. The fewer the number of wave action erosion days, the better.

**Performance Measure 2**
The second parameter emerged from discussions with First Nations. The method is based on the concept that keeping sites fully inundated can protect them from wind and wave erosion, as well as human disturbances. The number of days that the reservoir water level is at least 1 metre above each elevation band over the year is weighted by the number of sites known to exist within each band. The greater the number of inundation days, the better. A 1 metre buffer was applied to each elevation band to account for depth of erosion due to wave action.

## Calculation

For each scenario:

1. Assemble the simulated results for Kinbasket Reservoir elevations over 60 years (1940-2000; Figure 1).
2. Performance measure (1): Count the number of days over the year that the reservoir is within each elevation band for each of the 60 years.
   Weight each day by the relative day weights listed in the Table 1 above.
3. Performance measure (2): Count the number of days over the year that the reservoir is at least 1 metre above each elevation band and thus fully inundating each elevation band for each of the 60 years.
   Weight each day by the relative day weights listed in the Table 1 above.
4. Summarize all statistics (Figures 2 and 3).

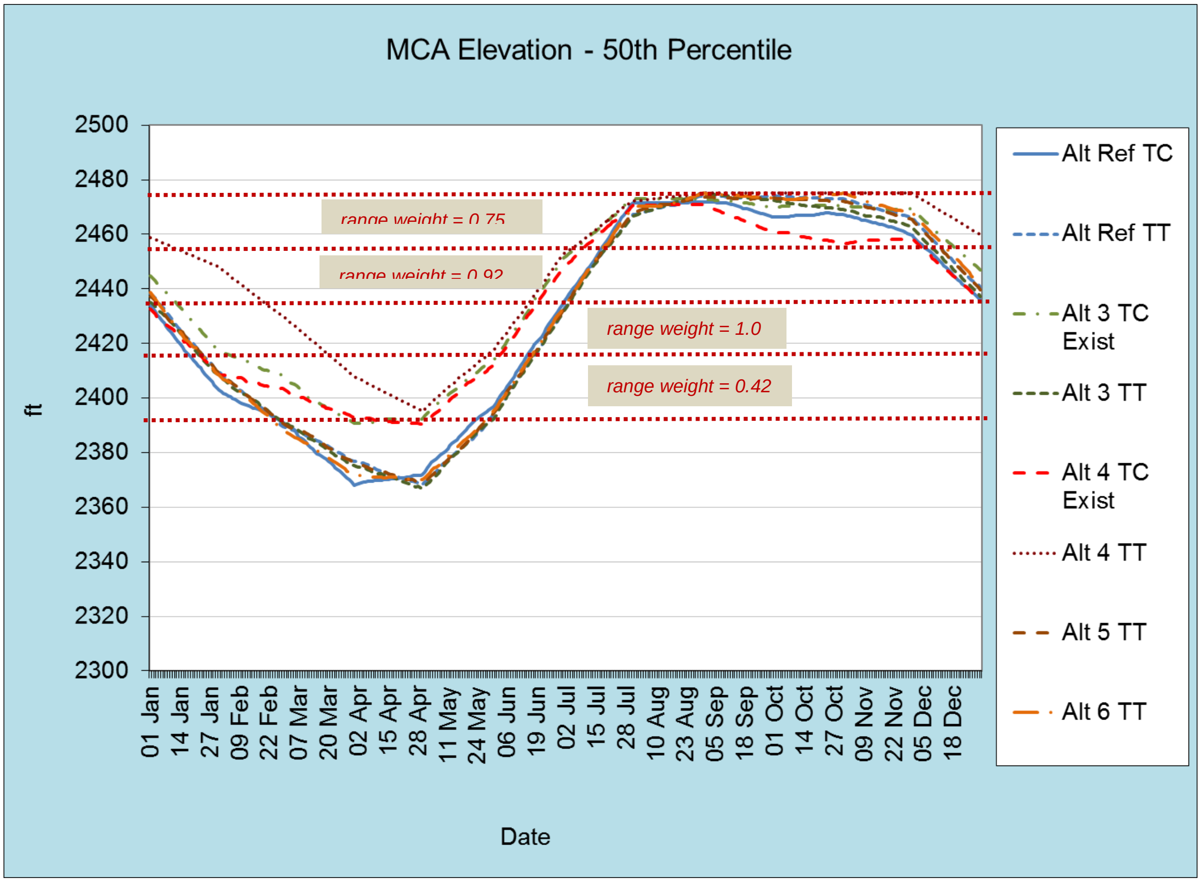


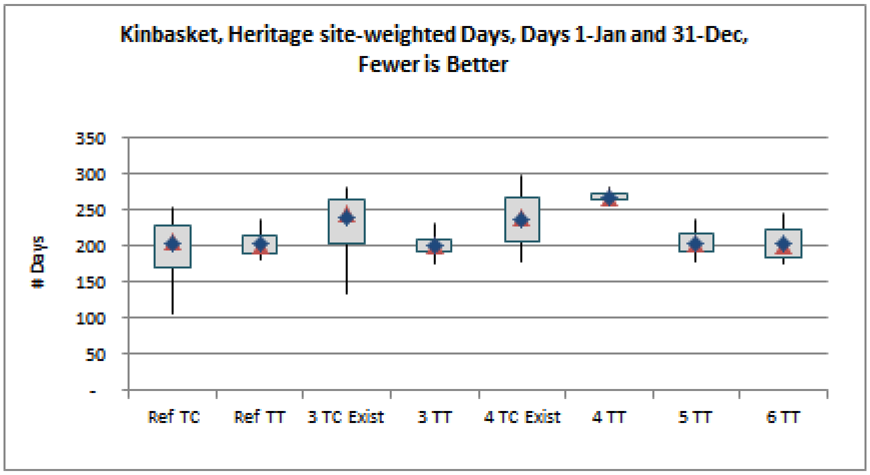

**Figure 1. Simulated Kinbasket Reservoir elevations. Median showing the weighted elevation bands for protection of identified heritage and cultural sites.**

## Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1929 – 1999).
- Assumes that the relative importance of any given recorded site is equal.
- Assumes that the relative survey effort across elevation zones is equal.

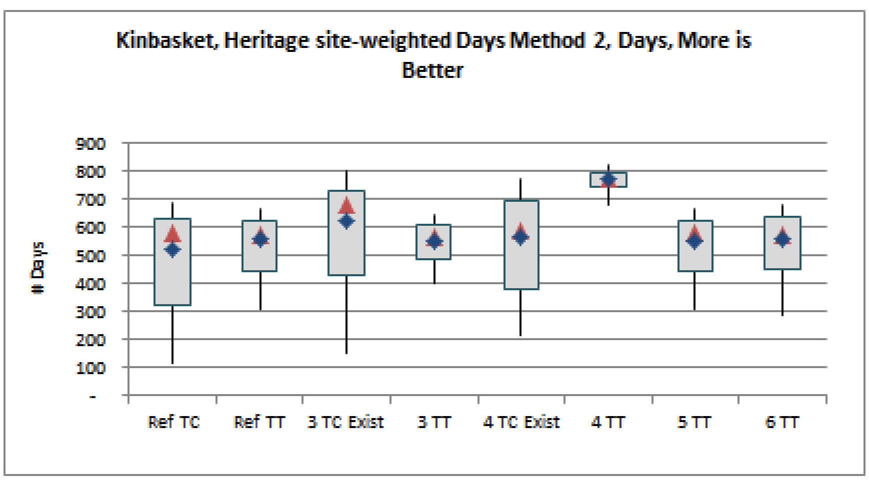
## Results

## Figure 2. Parameter (1): Erosion – Culture & Heritage




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 253 | 238 | 281 | 230 | 299 | 282 | 238 | 244 | Max |
| 228 | 214 | 265 | 208 | 268 | 272 | 216 | 223 | 90th |
| 206 | 202 | 245 | 200 | 239 | 267 | 204 | 201 | Med |
| 203 | 203 | 239 | 201 | 238 | 267 | 204 | 202 | Mean |
| 170 | 190 | 204 | 191 | 207 | 264 | 192 | 185 | 10th |
| 106 | 181 | 135 | 176 | 178 | 262 | 179 | 176 | Min |

## Figure 3. Parameter (2): Inundation – Culture & Heritage




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 690 | 667 | 800 | 644 | 772 | 823 | 665 | 677 | Max |
| 632 | 623 | 728 | 606 | 698 | 797 | 624 | 637 | 90th |
| 583 | 576 | 683 | 570 | 591 | 771 | 578 | 577 | Med |
| 524 | 556 | 627 | 555 | 568 | 770 | 555 | 559 | Mean |
| 325 | 447 | 429 | 487 | 381 | 745 | 443 | 455 | 10th |
| 114 | 313 | 152 | 400 | 218 | 679 | 311 | 286 | Min |

# PERFORMANCE MEASURE INFORMATION SHEET # 4

## KINBASKET RESERVOIR: EROSION

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Erosion / Kinbasket Reservoir | Erosion Control | # days per year | Sum of # days each year that the reservoir water level is at or above 2470 ft and potentially causing erosion and slumping of the upper elevations | 7 days per year |

## Description

During the Columbia WUP process, concern was expressed that surcharge of Kinbasket Reservoir may cause erosion from wave action and bank slumping, and affect property and logging roads adjacent to the reservoir. Surcharging may also mobilize debris that has accumulated along the shorelines. The full pool level of the reservoir is 2475 ft (754.38 m), and there are no structures within the surcharge area.

A performance measure was developed during the Columbia WUP process to track the number of days each year that Kinbasket Reservoir elevations would exceed full pool. However, the modelling results suggested the frequency of surcharge on Kinbasket Reservoir is low and unlikely to be affected by proposed operating alternatives being considered by the Committee. For this reason, this performance measure was not carried forward.

## Performance Measure

For the NTS analysis, a similar performance measure was developed to report out on erosion risk under each of the four scenarios being evaluated. This metric tracks the number of days that Kinbasket Reservoir would exceed 2470 ft (753 m).

## Calculations

For each scenario:

1. Assemble the simulated results for Kinbasket Reservoir elevations (1929-1999; Figure 1).
2. Count the number of days over the year that the reservoir is at or above the elevation threshold for each of the years.
3. Summarize all statistics (Figure 2).

## Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1929 – 1999).

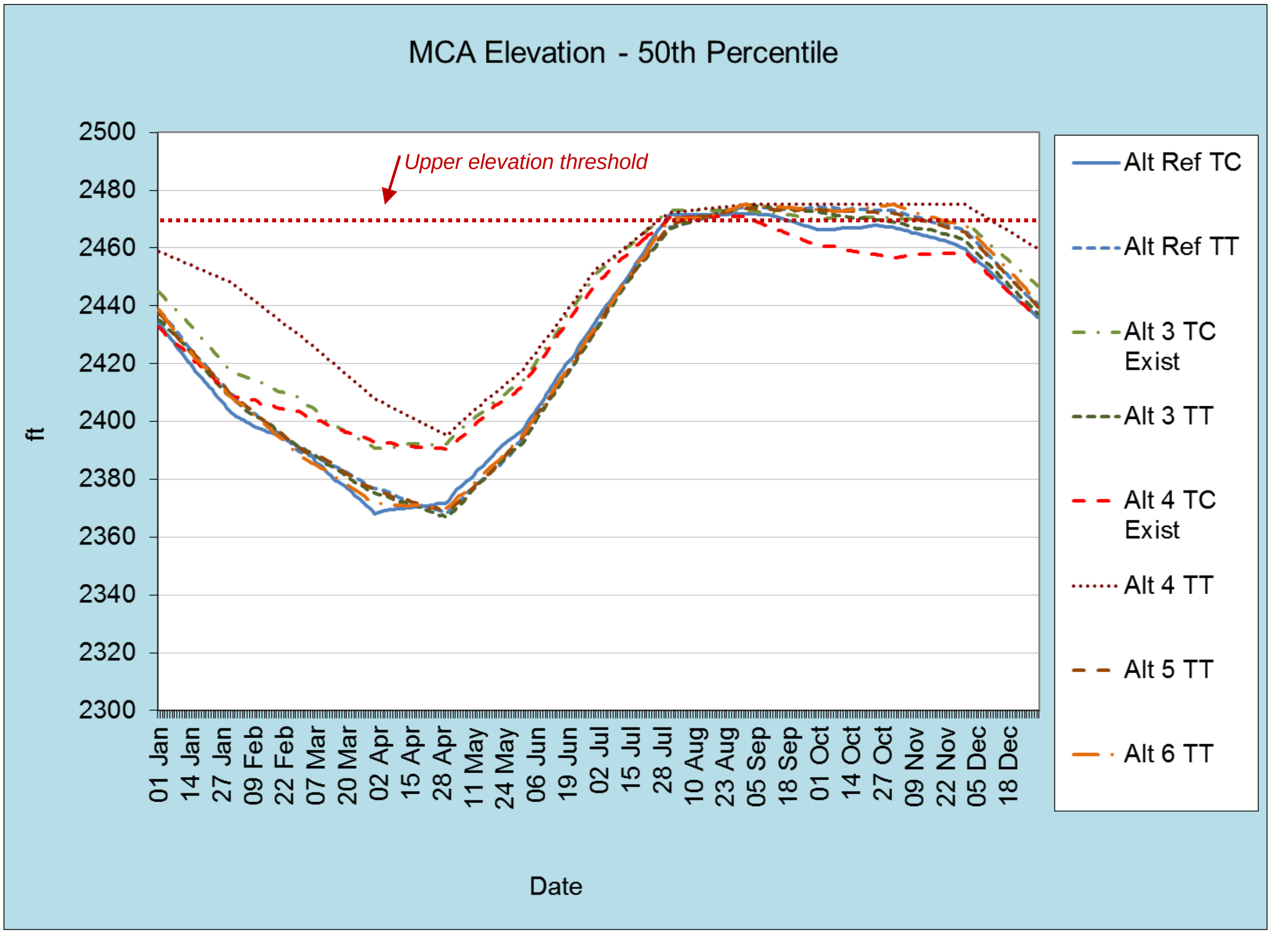
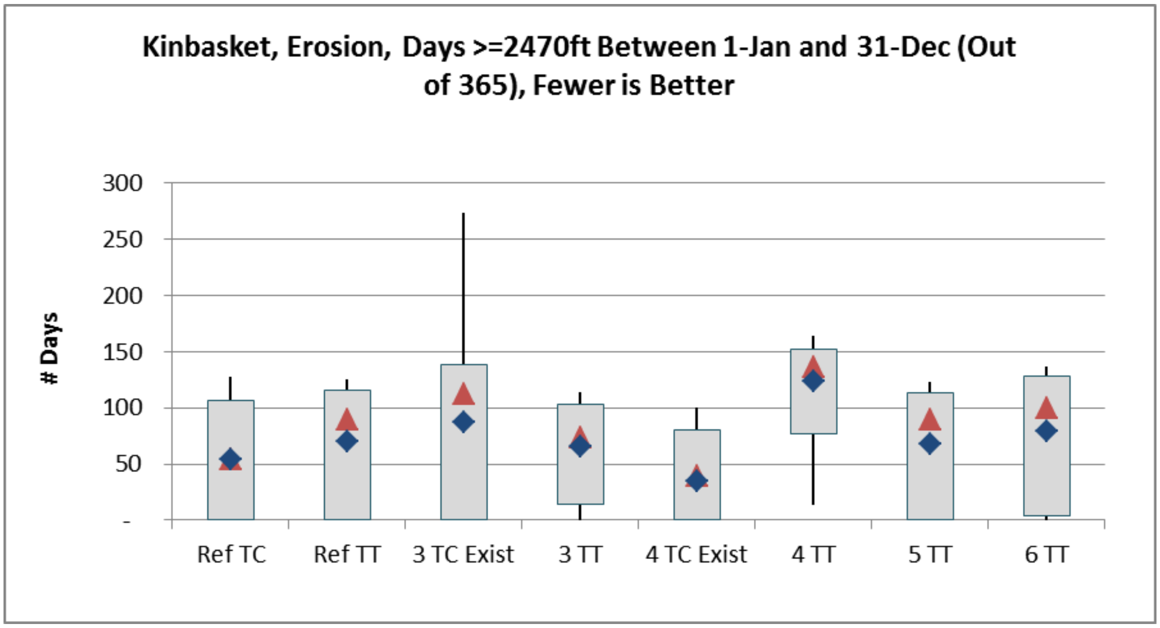



**Figure 1. Kinbasket Reservoir elevations. 50th percentile showing the elevation threshold for erosion.**

## Results

**Figure 2. Erosion (>= 2470 ft) –**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 128 | 125 | 274 | 114 | 100 | 164 | 123 | 137 | Max |
| 106 | 116 | 139 | 103 | 80 | 152 | 113 | 128 | 90th |
| 54 | 90 | 112 | 74 | 39 | 136 | 89 | 100 | Med |
| 54 | 70 | 87 | 65 | 35 | 123 | 68 | 79 | Mean |
| - | - | - | 14 | - | 77 | - | 4 | 10th |
| - | - | - | - | - | 13 | - | - | Min |

# PERFORMANCE MEASURE INFORMATION SHEET #5

## KINBASKET RESERVOIR: VEGETATION

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Vegetation/ Kinbasket Reservoir | Vegetation | Flooded weeks | Reports on number of 2 m elevation bands (ranging from 735 to 755 m) inundated more than 18 weeks per year<br><br>Lower is better | 10% |

## Description

A change over time in the composition and spatial extent of riparian vegetation (i.e., vegetation around the reservoir in the zone that is periodically inundated) is an indicator of the potential effects of BC Hydro operations on wildlife, aesthetics, and littoral productivity. Vegetation also improves aesthetic quality, helps to control dust, and may serve to protect cultural sites from erosion and human access.

Establishment of vegetation communities occurs to varying extents around the perimeter of Kinbasket Reservoir depending on substrate, slope, aspect and elevation. Given the large licensed drawdown of Kinbasket (~47 m), a key factor in vegetation establishment is the inundation regime of the reservoir. The specific effects of inundation on vegetation are thought to depend on the depth, duration, and timing of daily water level changes throughout the growing season. The stress on vegetation communities within the drawdown zone of Kinbasket Reservoir is exacerbated by high rates of deposition and erosion, which are atypical of shoreline flooding events associated with unregulated lakes or rivers. The degree of exposure and the slope of a flooded site largely determine if plants and substrates remain on site or are eroded away.

The WUP Consultative Committee made several assumptions regarding vegetation tolerances to inundation and responses to changes in the hydrologic pattern, based on information gained from studies in the Arrow Lakes Reservoir (AIM and Carr 2002, Moody 2002). Specifically, it was assumed that a change in hydrology (relative to historic) should dictate trends in vegetation by affecting the amount of land that is vegetated at lower elevations within the drawdown zone, or by affecting the amount of plant growth produced per unit area (biomass) and the number of species in the area (diversity) at upper elevations within the drawdown zone. Given differences in the elevation, climate and operating regime of the two reservoirs (Kinbasket and Arrow), the Committee recognized the inherent uncertainties of applying any findings related to the response of vegetation to reservoir operating conditions based on the Arrow Lakes Reservoir study to the Kinbasket Reservoir, and acknowledged the importance of longer-term data collection for assessing the effects of the Kinbasket operating regime on vegetation at multiple spatial scales.

Long-term monitoring programs being undertaken through BC Hydro’s Water License Requirements (WLR) Program have shown that vegetation communities, particularly those in the higher elevation bands (e.g., > 749 m), have developed over a number of years when Kinbasket Reservoir did not reach full pool. That is, vegetation communities that span the higher elevation bands experience less inundation and consequently have had more time to develop compared to communities in lower elevation bands. However, vegetation communities in Kinbasket Reservoir appear to be fairly dynamic, with species composition changing from one year to the next (Hawkes et al. 2008, 2009). Preliminary results from WLR studies suggest there have been subtle impacts to the spatial extent, structure and composition of existing vegetation communities resulting from reservoir operations. Since 2007, notable reductions have occurred in species diversity and richness for communities occurring at the highest elevation of the drawdown zone, and increases in diversity and richness for certain communities occurring lower down in the drawdown zone. It is postulated that the lower species diversity at higher elevations is linked to a full pool event in the summer of 2007. However, when considering the vegetation communities overall (i.e., across all elevations and sites), the distribution and extent of those communities has not changed markedly since 2007. To draw conclusions about the impact of the operating regime, further investigation is required, particularly across years where a time series analysis may provide better insight regarding the relationships between environmental conditions and species community richness.

In this analysis, the potential impacts of the CRTR alternatives on vegetation in Kinbasket Reservoir were evaluated using data from 1929 to 1999. Because Digital Elevation Modelling information is unavailable, results are presented in terms of inundated elevation bands.

## Calculations

Inundation statistics for the CRTR alternatives were computed for the combined periods May 1 – Aug 31 and Sep 1 – Sep 30 (representing the early and latter part of the growing season).

Using the simulated results for Kinbasket Reservoir elevations over 1929-1999 period the number of elevation bands (2 m in width) ranging from 735m to 755m, which are inundated for more than 18 weeks throughout both growing seasons, are summed for each year (Figure 1). The mean average of these totals is used in the consequence table.

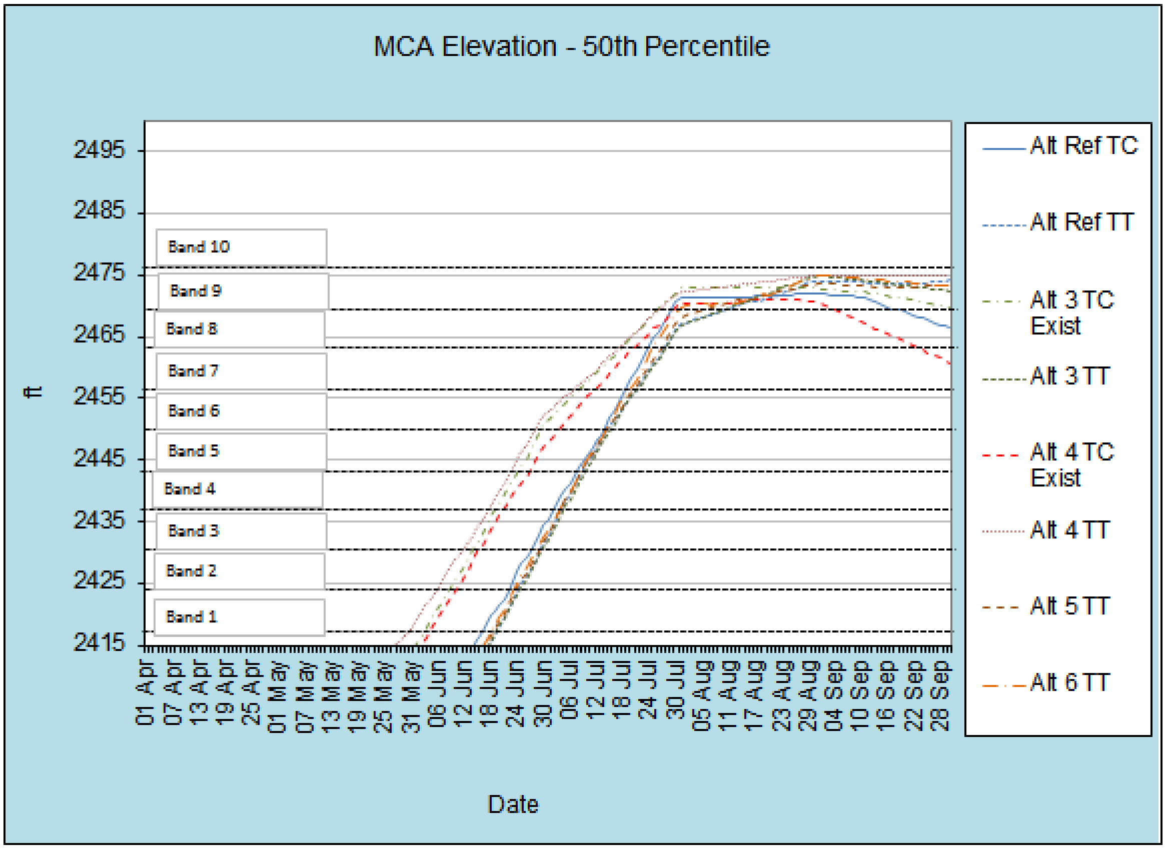



**Figure 1: Approximate elevations of elevation bands, converted to imperial units**

## Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows.
- Assumes frequency, duration and extent of inundation (timing, duration and depth) of inundation are the only drivers of vegetation survival/establishment
- Assumes all vegetation types are equally affected by the three drivers

## Results

The number of flooded weeks by elevation band are shown in two parts of Table 1.
In the top table, the number of weeks are colour-coded, with the lowest number of weeks flooded in green and the highest number in red. From this perspective, it is clear that alternatives 3TC, 4TC and 4TT have the longest durations of flooded weeks in the deeper elevations. This corresponds to the differentiation these three alternatives have on from the other alternatives during the May to July period in Figure 1.

**Table 1: Average flooded weeks by elevation band**

Flooded weeks (fewer = green, greater = red)

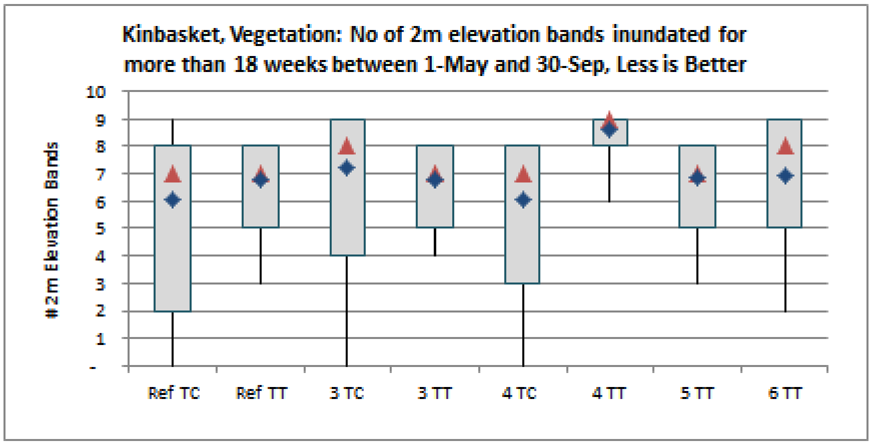
| | | Ref TC | Ref TT | 3 TC | 3 TT | 4 TC | 4 TT | 5 TT | 6 TT |
|---|---|---|---|---|---|---|---|---|---|
| Band 10 | >2477.0' | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Band 9 | >2470.5' | 6.8 | 9.3 | 11.0 | 8.6 | 4.4 | 17.2 | 9.0 | 10.7 |
| Band 8 | >2463.9' | 11.4 | 13.9 | 15.5 | 14.4 | 9.7 | 21.9 | 13.6 | 14.6 |
| Band 7 | >2457.3' | 14.2 | 17.5 | 18.6 | 17.9 | 14.9 | 24.9 | 17.1 | 17.8 |
| Band 6 | >2450.8' | 17.5 | 20.3 | 21.9 | 20.8 | 21.1 | 26.3 | 20.1 | 20.5 |
| Band 5 | >2444.2' | 20.4 | 23.2 | 24.2 | 23.1 | 24.9 | 27.4 | 23.0 | 22.9 |
| Band 4 | >2437.7' | 23.0 | 25.6 | 26.2 | 24.8 | 27.6 | 28.6 | 25.1 | 24.5 |
| Band 3 | >2431.1' | 25.3 | 27.7 | 28.2 | 26.1 | 29.7 | 30.0 | 27.0 | 25.9 |
| Band 2 | >2424.5' | 27.6 | 29.3 | 30.3 | 27.1 | 31.4 | 31.6 | 28.7 | 26.9 |
| Band 1 | >2418.0' | 29.7 | 30.6 | 32.4 | 27.9 | 32.9 | 33.3 | 30.2 | 27.9 |

More than 18 weeks (red)

| | | Ref TC | Ref TT | 3 TC | 3 TT | 4 TC | 4 TT | 5 TT | 6 TT |
|---|---|---|---|---|---|---|---|---|---|
| Band 10 | >2477.0' | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Band 9 | >2470.5' | 6.8 | 9.3 | 11.0 | 8.6 | 4.4 | 17.2 | 9.0 | 10.7 |
| Band 8 | >2463.9' | 11.4 | 13.9 | 15.5 | 14.4 | 9.7 | 21.9 | 13.6 | 14.6 |
| Band 7 | >2457.3' | 14.2 | 17.5 | 18.6 | 17.9 | 14.9 | 24.9 | 17.1 | 17.8 |
| Band 6 | >2450.8' | 17.5 | 20.3 | 21.9 | 20.8 | 21.1 | 26.3 | 20.1 | 20.5 |
| Band 5 | >2444.2' | 20.4 | 23.2 | 24.2 | 23.1 | 24.9 | 27.4 | 23.0 | 22.9 |
| Band 4 | >2437.7' | 23.0 | 25.6 | 26.2 | 24.8 | 27.6 | 28.6 | 25.1 | 24.5 |
| Band 3 | >2431.1' | 25.3 | 27.7 | 28.2 | 26.1 | 29.7 | 30.0 | 27.0 | 25.9 |
| Band 2 | >2424.5' | 27.6 | 29.3 | 30.3 | 27.1 | 31.4 | 31.6 | 28.7 | 26.9 |
| Band 1 | >2418.0' | 29.7 | 30.6 | 32.4 | 27.9 | 32.9 | 33.3 | 30.2 | 27.9 |

However, the bottom chart in table 1 shows that when using the 18 week flooding threshold, alternative 4TC is no worse than several other alternatives. This is because of the drawdown in the late season associated with this alternative. This is a better indicator of performance because extended periods of inundation beyond 18 weeks may not be significantly worse than being inundated for 18 weeks.

Figure 2 shows the statistical variation in the number of elevation bands flooded for more than 18 weeks. The mean number of bands flooded for more than 18 weeks per year is taken as the performance measure in the overall consequence table.




| Ref TC | Ref TT | 3TC | 3 TT | 4 TC | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 9 | 8 | 9 | 8 | 8 | 9 | 8 | 9 | Max |
| 8 | 8 | 9 | 8 | 8 | 9 | 8 | 9 | 90th |
| 7 | 7 | 8 | 7 | 7 | 9 | 7 | 8 | Med |
| 6.1 | 6.8 | 7.2 | 6.8 | 6.0 | 8.6 | 6.8 | 7.0 | Mean |
| 2 | 5 | 4 | 5 | 3 | 8 | 5 | 5 | 10th |
| - | 3 | - | 4 | - | 6 | 3 | 2 | Min |

**Figure 2. Average Number of Elevation Bands (m) Flooded for more than 18 weeks during both the Early and Late Growing Seasons for the Simulation Period**

# PERFORMANCE MEASURE INFORMATION SHEET #6

## KINBASKET RESERVOIR: DUST

| Objective / Location | Performance Measure | Units | Description |
|---|---|---|---|
| Dust Control/Kinbasket Reservoir | Dust potential days | Sq-km days | Reports on the total annual sq-km days of potential dust polygons in the drawdown zone that are exposed and therefore have potential to emit fugitive dust |

## Description

The operational regime of Kinbasket Reservoir is such that large areas (“beaches”) of the drawdown zone in Canoe Reach are sparsely vegetated or are denuded of vegetation altogether. Those areas have the potential to emit dust, which may potentially be carried by winds to and beyond the town of Valemount, located at the northern end of Canoe Reach.

An investigation into dust generation risk within Canoe Reach of Kinbasket Reservoir was conducted by LGL (Hawkes and Ferreira 2010), in which a series of high-level overview maps delineating the distribution of potential dust polygons in Canoe Reach were developed. To examine the relative dust generation risk associated with each of the six scenarios, a modeling exercise was undertaken based on the duration and area of the dust polygons exposed as a result of drawdown and the water elevation regime.

Within the LGL investigation, each polygon was assigned a dust contribution rating based on the hypothesized interaction of reservoir elevation (as a proxy for polygon exposure), substrate particle size, and per cent of vegetation cover. Substrate particle size and vegetation cover were not factored into this analysis because there are key data gaps that would have introduced significant error into the modeling. Particle size make-up of substrates in the drawdown zone is unknown for 41 per cent of the area covered by the dust polygons and vegetation cover[1] is known for only 15 per cent of the dust polygons. Modelling of these attributes would have required a large number of assumptions regarding elevation specific dust-emission rates, and uniformity of substrate type and per cent cover.

While historic meteorological conditions allow us to predict the extent to which future conditions might be conducive to dust storm events, future meteorological conditions are independent of reservoir operations and would apply equally to all four scenarios. As this information would not inform a *relative comparison* of the risks of dust emission under the six scenarios, these data were not considered in the model.

The simulated month-end reservoir elevations from HYSIM were used to determine the proportion of land exposed (i.e., not submerged) and therefore able to emit dust at some point in time from April to October under each of the alternatives. The total area exposed was used to rank the potential of each scenario to contribute to the emission of dust from the drawdown zone within Canoe Reach. In this analysis, it was postulated that the risk of a dust-storm event is related to duration and area of reservoir-bed exposure. First, a longer duration of exposure

[1] Vegetation cover can serve to reduce dust emissions by binding the substrate.

increases the probability that local meteorological conditions will be sufficient to initiate an event. Second, larger areas have greater potential for larger net volumes of dust emissions.

## Performance Measure

### Calculations

1. For each alternative and year of data, the area of exposed land was summed for 319 polygons identified based on their mean elevations..
2. For each alternative and year the number of "square-kilometre-days" (sq-km-days) was calculated. These were summed and the yearly total sq-km days were used as a basis for comparing the alternatives. These units are represented by the sum of the area of land that is above a given reservoir elevation (i.e., it is exposed) during the period of April 1 to October 31 for each year.

### Key Limitations

- Wave action is not considered in the model. Although higher winds can be expected to be capable of causing higher emission rates, net emission could be offset to the extent that wind-waves cause wetting of surface materials above the standard reservoir elevation.
- Emission rates within and among different substrate types have not been calculated or ranked. It is expected that lower elevations will have higher emission rates due to: (i) greater proportion of finer particles, (ii) less vegetation cover, and (iii) less woody debris cover. As such, elevation-specific emission rates could increase with decreasing elevation. This compounds (as opposed to mitigate) dust emissions at lower water levels.
- The distribution of vegetation, which serves to mitigate dust emissions, has not been mapped throughout the entire drawdown zone of Canoe Reach.

### Key Assumptions

- Assumes that the water level (elevation) in Canoe Reach equals that in the Mica Dam forebay.
- Assumes emission rates are constant over time and space (e.g., a lack of submergence in Year 1 does not affect emission rates in years 1 + n). It is possible that emission rates in Year n are not independent of water levels in previous years; flooded beaches can receive silt deposits that are then available to become dust when that area is next exposed. Thus, consecutive low-water years could serve to mitigate dust potential due to (i) reduced siltation deposits, (ii) increased vegetation growth, and (iii) increased losses to aeolean processes.
- Exposed areas within the drawdown zone have potential for fugitive dust emissions, regardless of substrate type; submerged areas have no such potential.

### Results

Figure 1 shows statistics on the total number of square-kilometre days for each of the six scenarios for all 319 polygons. The results for the six scenarios are quite similar. Of the six scenarios, 4TT appears to have the lowest dust-risk potential, but not by a significant margin. The treaty terminates scenarios appear to have less variability in their results in comparison to the treaty continues scenarios.

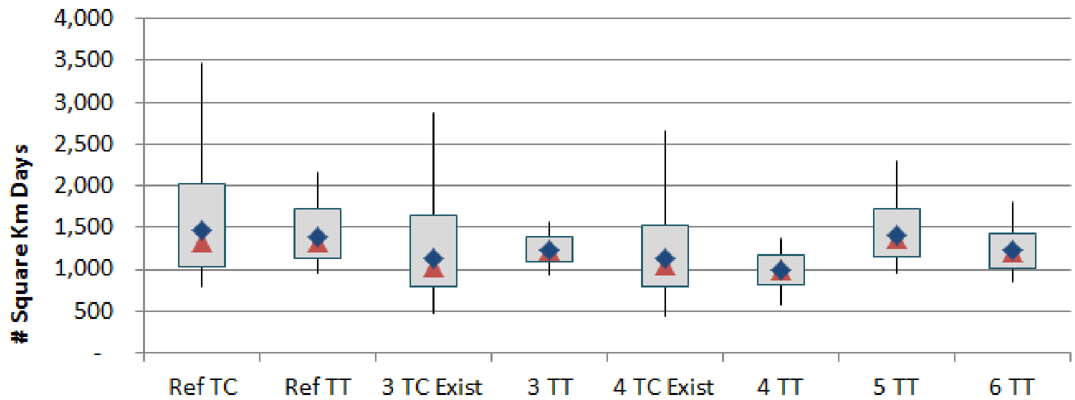



**Figure 1. Summary of Square-kilometre Days for each Scenario during the period of April through October for HYSIM Data spanning years 1929-1999.** Data are for all areas identified within the LGL investigation. Plots show the mean, median, 10% and 90% percentiles (lower and upper limits of boxes), and minimum and maximum values (lower and upper limits of vertical lines).

## References

Demarchi, M. and V. Hawkes. 2010. Kinbasket Reservoir, Comparison of Dust Emission Risks in Canoe Reach among four NTS scenarios. LGL Report EA3211 prepared for BC Hydro Generation Resource Management by LGL Limited environmental research associates. 17pp. plus appendix.

Hawkes, V. anad L. Ferria. 2010 Kinbasket Reservoir. Valemount/Canoe Reach Dust Source Assessment. LGL Report EA3211 prepared for BC Hydro Generation Resource Management by LGL Limited environmental research associates. 15pp. plus appendices.

# PERFORMANCE MEASURE INFORMATION SHEET #7
# KINBASKET AND ARROW LAKES RESERVOIRS: PRODUCTIVITY

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Productivity/ Kinbasket Reservoir | Residence Time | Days per year over the period of growing season: 1 April to 30 September (Kinbasket) | Average number of days for water to travel through the reservoir.<br><br>More is better | 10% |
| Productivity/ Arrow Lakes Reservoir | Epilimnetic Residence Time | Days per year over the period of growing season: 1 April to 30 September (Arrow) | Average number of days for the top 20m water to travel through the reservoir.<br><br>More is better | 10% |

## Description

Annual nutrient load and resultant pelagic productivity are the ‘drivers’ of annual phytoplankton carbon production cycles upon which kokanee populations are dependant. For Arrow Reservoir, there is a large extant database on phytoplankton production and biomass, as well as light, temperature and mainstem and tributary flow data, but for Kinbasket Reservoir, there is less historic data available. These data are now being obtained through the Kinbasket Reservoir ecological productivity monitoring program being undertaken through BC Hydro’s Water License Requirement Program. However, this project is in its early stages of implementation and it is too early to analyze the data to better understand the role of nutrients, temperature and light in determining pelagic productivity of Kinbasket Reservoir.

For the purposes of the 2010 NTSA analysis, the pelagic euphotic zone was used as a measure of pelagic productivity for the two reservoirs. However, during a review of this work for the CRTR, the CRTR-FWC wished to explore different ways of considering this issue.

For Kinbasket reservoir, it was decided to use growing season residence time as a proxy for pelagic productivity. The entire reservoir volume is considered since Kinbasket reservoir has a deep penstock intake that draws in cold, hypolimnetic water.

For Arrow Lakes reservoir, it was thought that the turnover rate of epilimnetic water was of greater significance. This is because Hugh Keenleyside dam discharges are drawn from a relatively shallow point and a largely unmixed layer of surface water could pass through more rapidly than if the full volume of the reservoir were considered.

## Performance Measure: Kinbasket Residence Time

Residence time is the length of time taken for water to travel through an impounded body of water. Residence time influences pelagic productivity and the amount of phytoplankton and carbon production cycles upon which fish populations are dependent. For the purposes of this analysis, residence time is used as a measure of pelagic productivity. A higher residence time increases pelagic productivity.

## Calculations

For each alternative:

Growing season average volume for each year:
1) Assemble the elevations in Kinbasket from 1 April to 30 Sept for each year.
2) Convert 1) to active storage volume in $m^3$
3) Average to get growing season average live volume for each year.
4) Add 8MAF of dead storage volume

Average daily discharge
1) Assemble the discharges from Mica from 1 April to 30 Sept for each year
2) Convert 1) to a discharge rate in $m^3$ per day
3) Average to get growing season average daily discharge for each year.

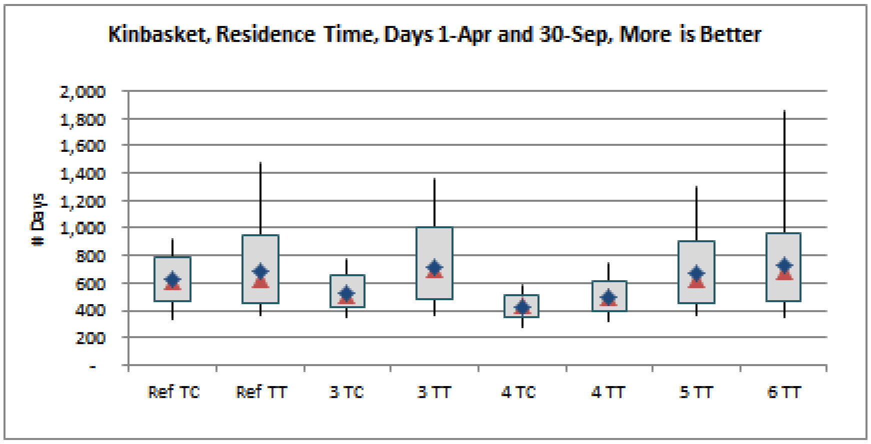
Summarize all statistics (Figures 1).

## Key Assumptions and Limitations

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1941 – 1999).
- Assumes nutrient levels and temperature are the same across the alternatives and can be safely ignored in the analysis.

## Results

Figure 1 shows the ‘growing season residence time’ for Kinbasket reservoir (i.e. the time that would be taken for the average growing season volume to be discharged at the average growing season discharge rate).




| Ref TC | Ref TT | 3TC | 3 TT | 4 TC | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 923 | 1,472 | 766 | 1,361 | 586 | 747 | 1,305 | 1,859 | Max |
| 782 | 944 | 651 | 1,010 | 506 | 615 | 897 | 969 | 90th |
| 614 | 630 | 508 | 698 | 431 | 489 | 628 | 681 | Med |
| 622 | 687 | 529 | 709 | 427 | 496 | 670 | 727 | Mean |
| 463 | 455 | 422 | 474 | 345 | 394 | 451 | 466 | 10th |
| 329 | 357 | 342 | 360 | 273 | 313 | 359 | 350 | Min |

**Figure 1. Kinbasket Residence Time expressed as average number of days per year**

Scenario 4TC results in the lowest average residence time of all alternatives. The treaty terminates scenarios (Ref TT, 3TT, 4TT, 5TT and 6TT) all have a higher residence time than the treaty continues scenarios (Ref TC, 3TC and 4 TC). Scenario 6TT has the highest average residence time but not by a significant amount.

Figure 2 helps to illustrate why Alts 3TC, 4TC and 4TT have a lower residence time: despite having a reduced drawdown in Kinbasket relative to Ref TC and the other alternatives, these alternatives each have a higher discharge rate during the period of interest.

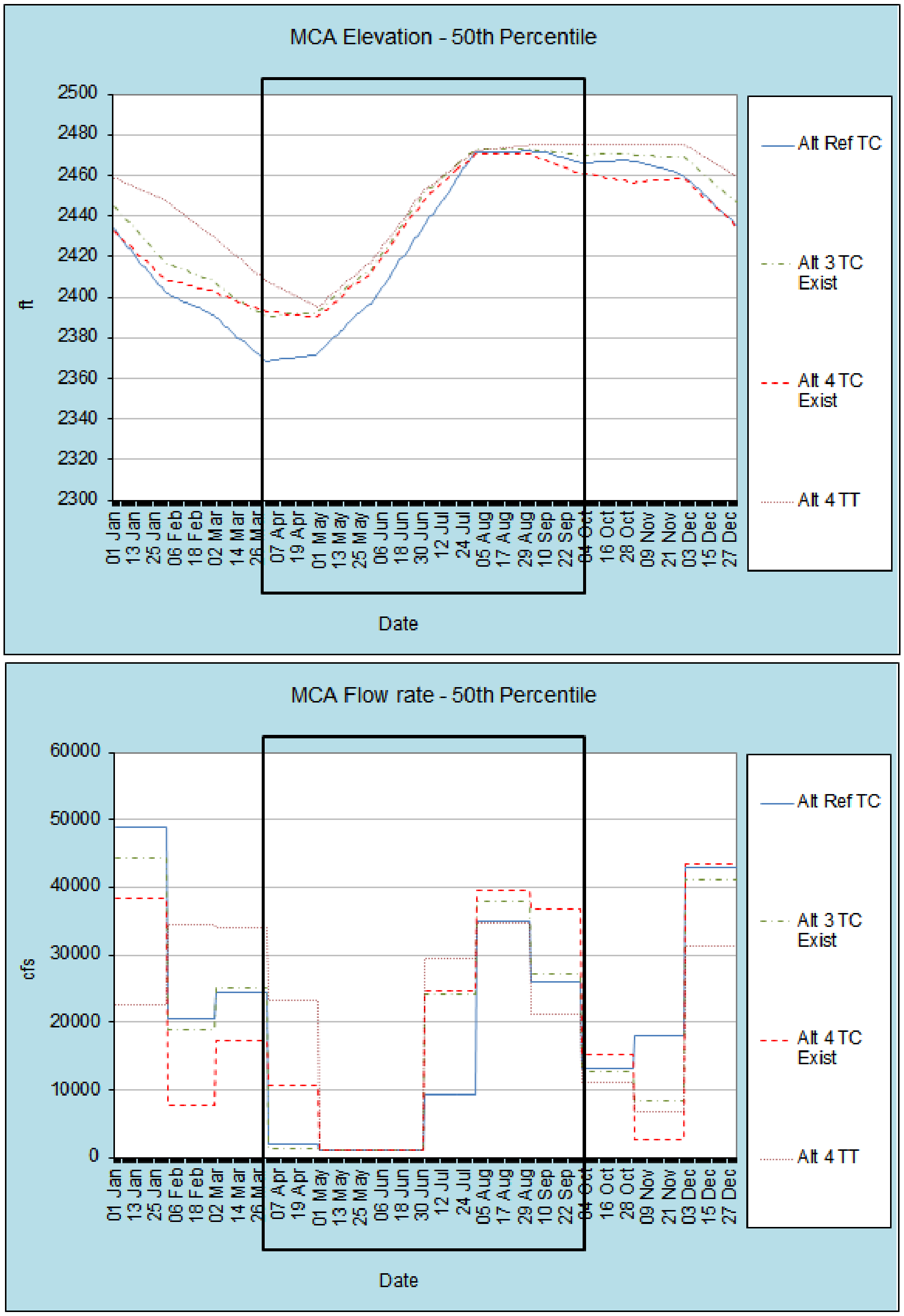



**Figure 2: Kinbasket elevation and Mica discharge during the growing season**

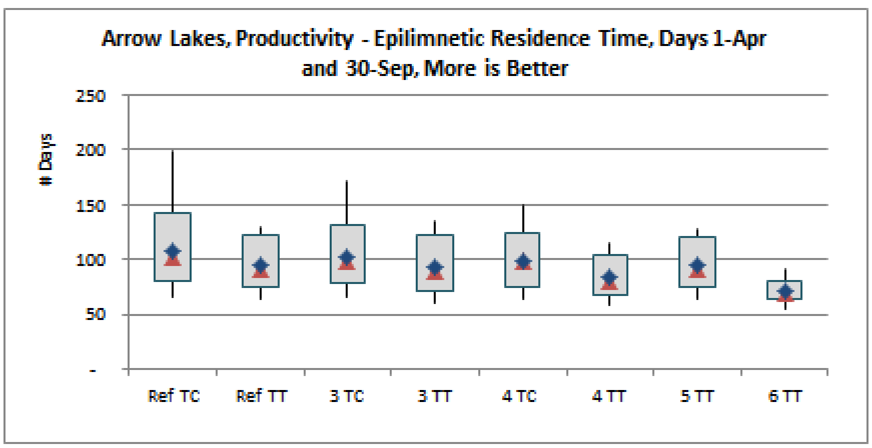
## Performance Measure: Arrow Lakes Reservoir Epilimnetic Residence Time

Arrow Lakes reservoir has outflows near the surface, and therefore has selective withdrawal of surface water. Epilimnetic residence time is the length of time taken for the top 20m of water to travel through the reservoir. This residence time influences pelagic productivity and the amount of phytoplankton and carbon production cycles upon which fish populations are dependent. For the purposes of this analysis, residence time is used as a measure of pelagic productivity. A higher residence time increases pelagic productivity.

## Calculations

1) Assemble the daily elevations of Arrow Lakes reservoir for the period 1 April and 30 September
2) For each daily elevation lookup the surface area in $m^2$. Where possible, lookup the surface area at the elevation minus 20m and average the two.
3) Multiply 2) by 20m to estimate the average epilimnetic volume on any given day.
4) Read the daily discharge from HLK dam in cfs between 1 April and 30 September and convert to $m^3$ / day.
5) Dividing the epilimnetic volume by the daily discharge rate gives number of days it would take to discharge the epilimnetic volume.
6) Summarize all statistics

## Results




| Ref TC | Ref TT | 3TC | 3 TT | 4 TC | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 199 | 129 | 172 | 135 | 149 | 115 | 128 | 91 | Max |
| 143 | 122 | 131 | 123 | 124 | 104 | 120 | 80 | 90th |
| 102 | 92 | 98 | 89 | 98 | 81 | 91 | 69 | Med |
| 107.1 | 94.8 | 101.3 | 93.4 | 98.2 | 83.5 | 93.9 | 70.1 | Mean |
| 81 | 74 | 79 | 72 | 75 | 68 | 74 | 64 | 10th |
| 66 | 63 | 65 | 60 | 63 | 58 | 63 | 55 | Min |

**Figure 1: Arrow Lakes Reservoir, Epilimnetic Residence Time**

Alternative 6TT has the shortest residence time. The treaty terminate alternatives have a slightly lower epilimnetic residence time than the treaty continues alternatives.

# PERFORMANCE MEASURE INFORMATION SHEET # 10

## MID COLUMBIA RIVER: RECREATION

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Recreation/Mid Columbia River | Access Days | # access days by activity by region | Sum of # days reservoir elevation is within the preferred range for shore-based and water-based activities | 7 days |

## Description

The City of Revelstoke supports a variety of day use recreation activities along the shoreline and on the mid Columbia River (downstream of Revelstoke Dam to Shelter Bay). The nature of recreational activity in this area is notably different from the upstream area, and is associated largely with near-urban opportunities along waterfront areas. Recreational opportunities include hiking, biking, walking, viewing and picnicking, boating and fishing.

The local community benefits from improvements to the quality and diversity of recreation and tourism experiences through a greater quality of life, as well as through local economic development benefits that result from increased usage. A number of key factors that affect recreational quality and use include:

- Diversity and abundance of fish and wildlife, since many recreational activities are focused on enjoyment of these natural resources
- Ability to safely access the water or shorelines for water-based and shore-based activities
- Visual quality of viewscapes (appearance of the river related to avoidance of exposed mudflats/dust)
- Avoidance of navigational hazards

## Performance Measure

During the Columbia WUP process, developing a recreation PM for this section of the system presented a special challenge because recreational opportunities are influenced both by flows in the river and by the elevation of Arrow Lakes Reservoir to different extents at different times of the year. The Recreation Technical Subcommittee suggested that a PM be developed that incorporates both these issues for motor boating and shoreline use. These two activities were chosen because they broadly represented a range of other uses. For example, “shoreline use” also refers to non-motorized boating activities that rely on easy access to the shoreline. However, data on preferred flows associated with activities on the mid Columbia River were particularly weak and a more formal investigation into the relationship between Columbia flows and Arrow elevations and the impact of this relationship on recreation would have been required.

For boat access, the Recreation Technical Subcommittee identified preferred elevations over the recreation season that would provide "good opportunity" for a broad range of interests, including access via boat ramps, usability of boat ramps, quality of boating within that range of elevations, and fishing opportunities. The boat access measure was not tied directly to physical structures (i.e., boat ramps). The shoreline access measure was defined around a range of elevations that constituted "good opportunity" for shore-based activities, with activities decreasing in frequency when the water is above this elevation threshold.

The elevation thresholds were developed based on critical water levels for viewshed quality, shore-based activities and water-based activities, as summarized in RL&L (2001).

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**PM Definitions**

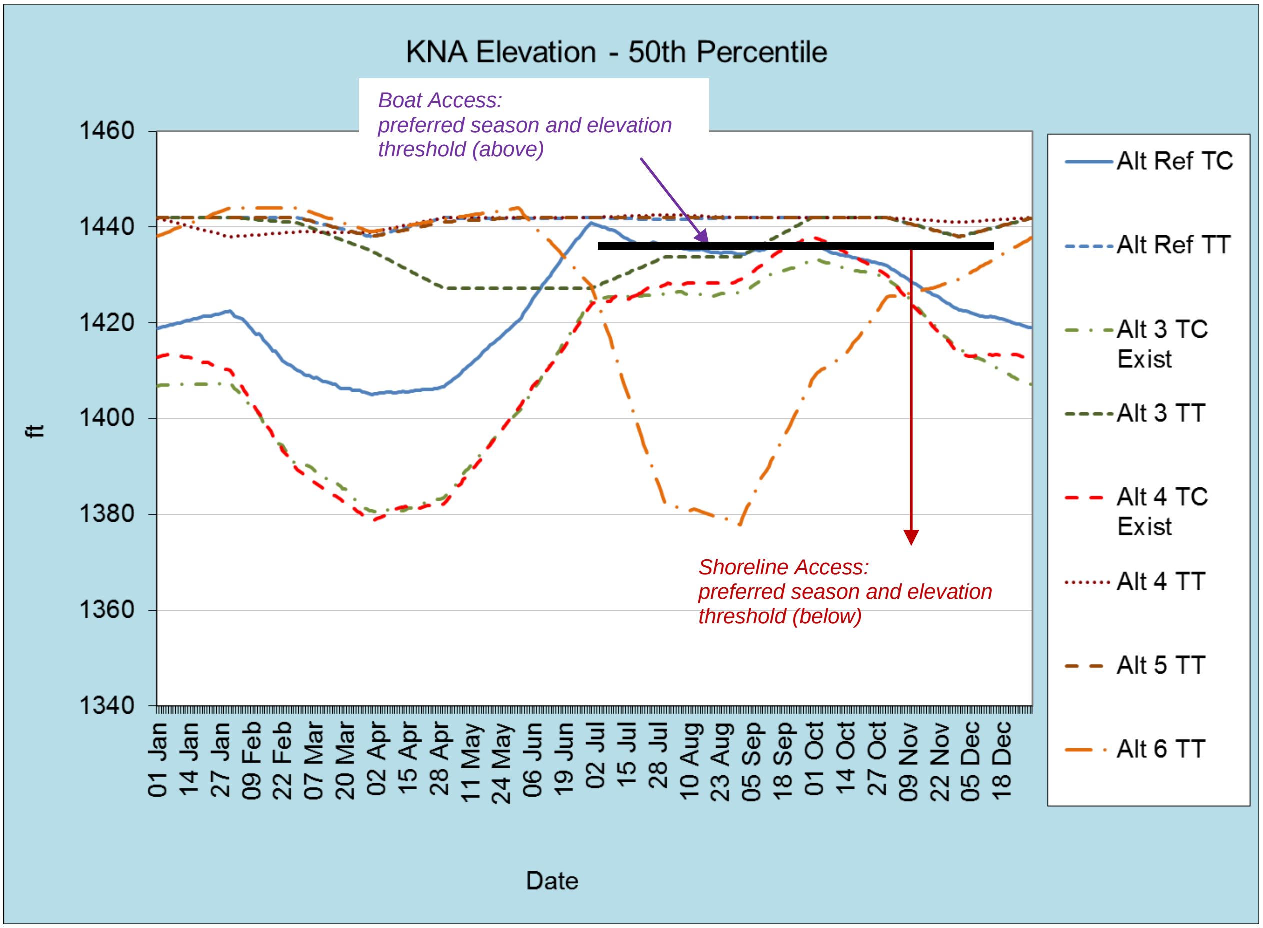
| Area | Measure | Dates | Critical Elevation Zone |
|---|---|---|---|
| Arrow Lakes Reservoir | Boat Access Days | 01 May to 30 Sept | # days at or above 1435 ft |
| | Shoreline Access Days | 01 April to 30 Sept | # days below 1435 ft |

## Calculations

For each scenario:

1. Assemble the simulated results for month-end reservoir elevations years 1929-1999; Figure 1).
2. Count the number of days over the defined recreation season that the reservoir water levels fall above the threshold for boat access and below the threshold for shoreline access.
3. Summarize all statistics (Figures 2 and 3).

**Figure 1. Mid Columbia River (Arrow Lakes) elevations. Median over 60 years showing the preferred elevation threshold for recreation (boat access and shoreline access).**

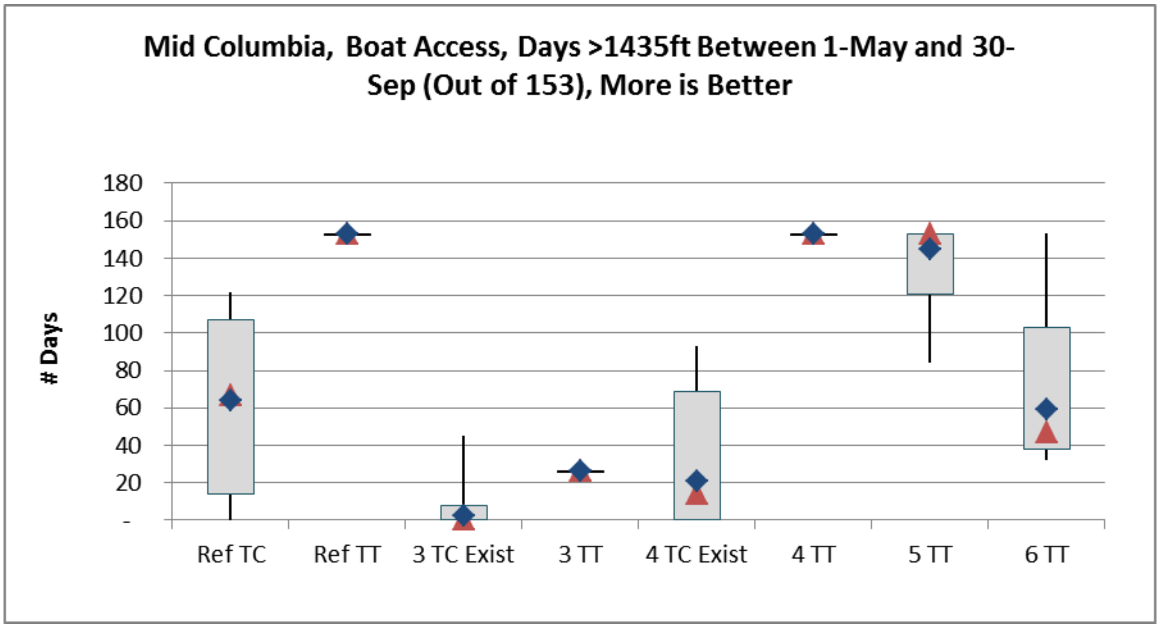



## Key Assumptions and Uncertainties

- Each alternative is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1929 – 1999).
- Assumes that there is minimal recreational use outside the defined recreation season.
- Assumes that the preferred season and elevations are accurate.
- Uncertain whether the preferred recreation elevations for the mid Columbia River are capturing the essence of access issues for boating and shoreline use.

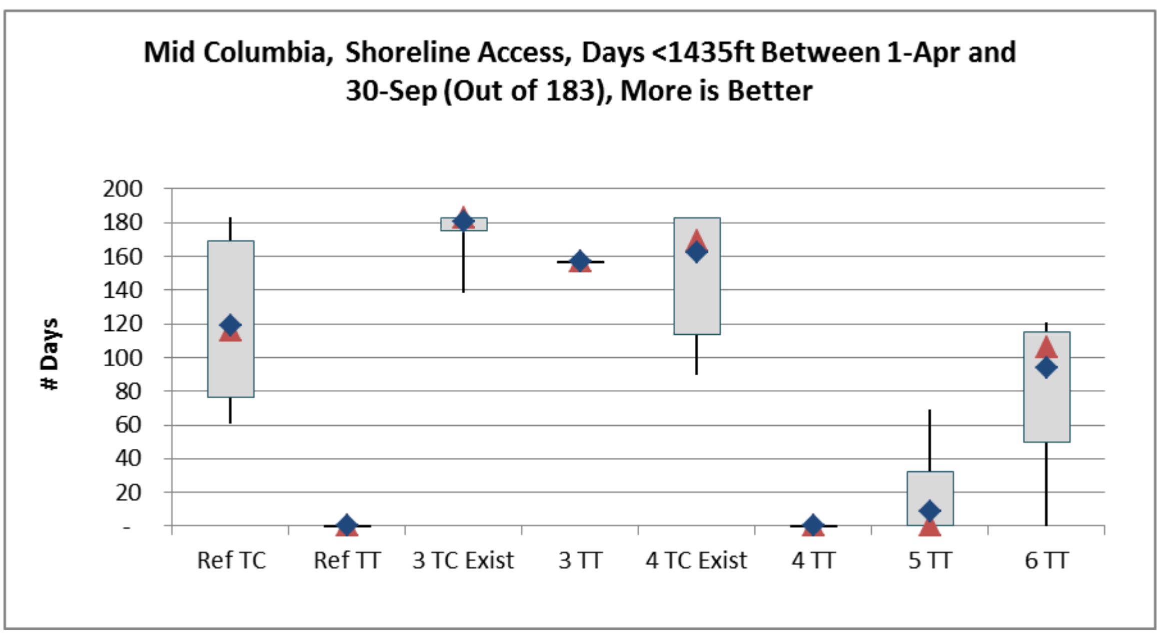
## Results

**Figure 2. Boat Access Days –**

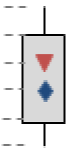



| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 122 | 153 | 45 | 26 | 93 | 153 | 153 | 153 | Max |
| 107 | 153 | 8 | 26 | 69 | 153 | 153 | 103 | 90th |
| 67 | 153 | - | 26 | 14 | 153 | 153 | 47 | Med |
| 64 | 153 | 2 | 26 | 21 | 153 | 145 | 59 | Mean |
| 14 | 153 | - | 26 | - | 153 | 121 | 38 | 10th |
| - | 153 | - | 26 | - | 153 | 84 | 32 | Min |

**Figure 3. Shoreline Access Days –**



| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 183 | - | 183 | 157 | 183 | - | 69 | 121 | Max |
| 169 | - | 183 | 157 | 183 | - | 32 | 115 | 90th |
| 116 | - | 183 | 157 | 169 | - | - | 106 | Med |
| 119 | - | 181 | 157 | 162 | - | 8 | 94 | Mean |
| 76 | - | 175 | 157 | 114 | - | - | 50 | 10th |
| 61 | - | 138 | 154 | 90 | - | - | - | Min |



## References

RL&L Environmental Services Ltd. 2001. Water Use Plans – Environmental information review and data gap analysis. Volumes 1 & 2. Prepared for BC Hydro, Burnaby by RL&L Environmental Services in association with Robertson Environmental Services Ltd., Pandion Ecological Research Ltd., Bruce Haggerstone Landscape Architect, Pomeroy & Neil Consulting Ltd. and DVH Consulting. RL&L Report No. 858V1-F.

# PERFORMANCE MEASURE INFORMATION SHEET #11

## MID COLUMBIA RIVER: VEGETATION

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Vegetation/ Mid Columbia River | Vegetation | Flooded Hectares | Hectares flooded for more than 18 weeks | 10% |

## Background

The depth, timing and duration of flooding of the Revelstoke Reach of the Arrow Lakes Reservoir are important factors that affect the species composition, spatial extent and diversity of vegetation in the drawdown zone. The WUP Consultative Committee focused a great deal of attention on the issue of vegetation in the mid Columbia River and the Arrow Reservoir drawdown zone since it supports a large number of other interests, including: birds and wildlife, protection of archaeological sites, dust control and aesthetic values.

The measurement of "what's good for vegetation" is complex, and the WUP Consultative Committee explored several different approaches to this. The development of a performance measure to track the impact of operations on vegetation was difficult due to the complexity of what drives the establishment and survival of vegetation in the drawdown zone, and significant data gaps that existed around the functioning of vegetation in a reservoir environment. A number of long-term monitoring programs are being undertaken through BC Hydro's Water License Requirements (WLR) Program to better understand the importance of the inundation regime, specifically the timing (i.e., early vs. latter part of the growing season), and other factors that play a role in determining why and how plants can survive in the drawdown zone.

Preliminary findings from ongoing WLR work indicate that there are a number of factors that influence vegetation establishment, species composition and spatial extent, including exposure to wave erosion, substrate type, ground water availability, and slope. Further, several vegetation types are exhibiting local adaptations to environmental conditions in the drawdown zone. While the water regime is likely a key determinant of vegetation presence and composition at the lower elevations (434-436 m; 1423.5-1430 ft), other factors play important roles at mid and higher elevations. Multiple years of data will be required to sort out the all of the key drivers of change and determine the relative importance of the many environmental variables that act on vegetation in the drawdown zone.

## Performance Measure

The potential impacts of on vegetation were determined based on inundation statistics for the Revelstoke Reach area, which take into account simulated reservoir elevation, local inflow and discharge releases from Revelstoke Dam. Inundation statistics were chosen because current data suggest that the duration, depth and timing of inundation are important factors affecting vegetation establishment and composition, especially at lower elevations of the drawdown zone. While other factors may be equally, or even more important, for certain vegetation types and elevations, current research is not far enough advanced to include these data in the model.

## Calculations

The most recent version of the HEC-RAS model for the mid Columbia River was used to estimate water surface elevations throughout the Revelstoke Reach[1]. The model is driven by Arrow Reservoir elevations (at Fauquier), discharge from Revelstoke Dam and estimated local inflows. Water surface elevations are predicted for every week of the 10-year simulation period (1964 to 1973) based on the average local inflow by week, the average reservoir elevation by week, and the maximum hourly discharge from Revelstoke Dam by week.

The number of weeks over the growing season (April 1 to October 15 or model weeks 14-41) during which each 1 m elevation band is inundated are computed for each year. This statistic can be used to evaluate the effects of flooding on vegetation biomass and species composition at various elevations within the Revelstoke Reach.

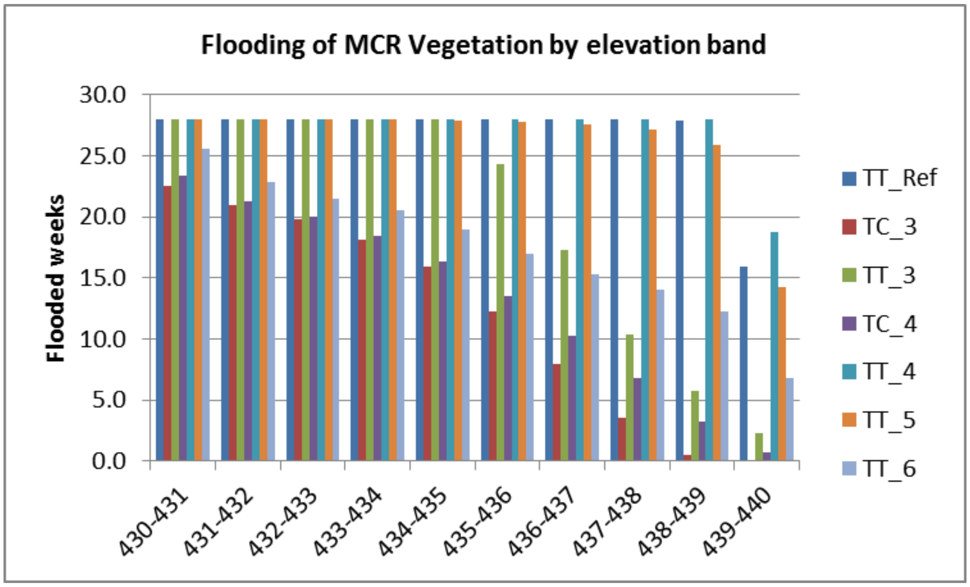
## Key Assumptions and Uncertainties

- Each alternative is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows.
- Assumes frequency, duration and extent (timing, duration and depth) of inundation are the only drivers of vegetation survival/establishment.
- Assumes all vegetation types are equally affected by the three drivers.

## Results

[1]Inundation statistics were only generated for Revelstoke Reach and assumed to be directionally applicable to the entire reservoir (i.e., higher water levels for longer periods during the growing season is “bad” for vegetation). Results of the WLR monitoring programs are indicating that vegetation communities between Revelstoke Reach and Arrow Reservoir are distinctly different in terms of species composition, species richness and abundance, and are likely to respond differently across elevation bands to the inundation regime due to difference in environmental conditions.

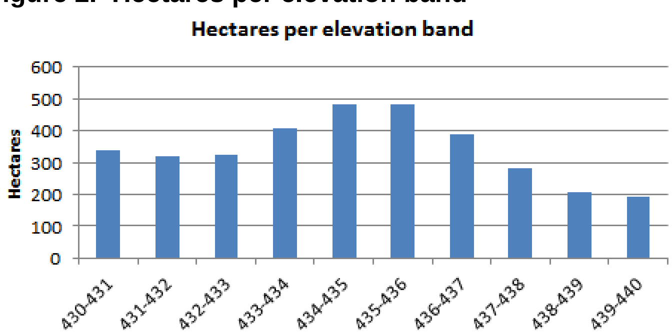
**Figure 1. Average Number of Flooded Weeks by 1-m Elevation Bands during the full Growing Season**




| | TC_Ref | TT_Ref | TC_3 | TT_3 | TC_4 | TT_4 | TT_5 | TT_6 |
|---|---|---|---|---|---|---|---|---|
| 430-431 | 25.1 | 28.0 | 22.5 | 28.0 | 23.4 | 28.0 | 28.0 | 25.6 |
| 431-432 | 23.8 | 28.0 | 20.9 | 28.0 | 21.3 | 28.0 | 28.0 | 22.8 |
| 432-433 | 23.0 | 28.0 | 19.8 | 28.0 | 20.0 | 28.0 | 28.0 | 21.5 |
| 433-434 | 21.6 | 28.0 | 18.2 | 28.0 | 18.4 | 28.0 | 28.0 | 20.5 |
| 434-435 | 20.1 | 28.0 | 15.9 | 28.0 | 16.3 | 28.0 | 27.9 | 19.0 |
| 435-436 | 18.5 | 28.0 | 12.2 | 24.3 | 13.5 | 28.0 | 27.8 | 16.9 |
| 436-437 | 16.3 | 28.0 | 8.0 | 17.3 | 10.2 | 28.0 | 27.6 | 15.3 |
| 437-438 | 12.6 | 28.0 | 3.5 | 10.3 | 6.9 | 28.0 | 27.2 | 14.1 |
| 438-439 | 8.1 | 27.8 | 0.6 | 5.7 | 3.2 | 28.0 | 25.9 | 12.2 |
| 439-440 | 2.9 | 15.9 | 0.0 | 2.3 | 0.7 | 18.8 | 14.3 | 6.9 |

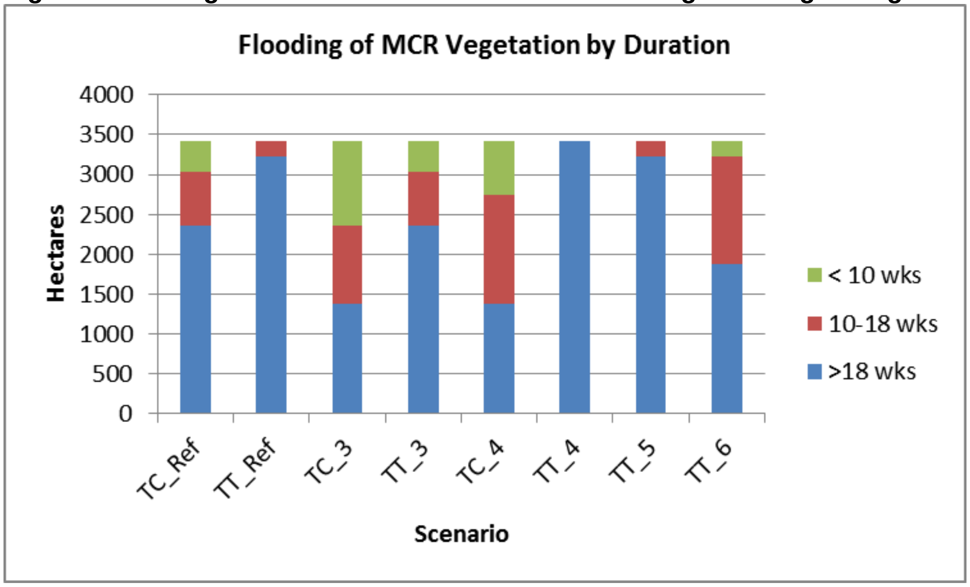
For the MCR, hectares of habitat available at each band level are available (Figure 2):

**Figure 2. Hectares per elevation band**




Combining data in Figures 1 and 2 results in Figure 3, which shows the combined hectares flooded grouped by duration of flooding. This more clearly indicates the increased flooding resulting from the TT_Ref, TT_4 and TT_5 alternatives.

**Figure 3. Average Number of Flooded Hectares during the full growing season**




| | TC_Ref | TT_Ref | TC_3 | TT_3 | TC_4 | TT_4 | TT_5 | TT_6 |
|---|---|---|---|---|---|---|---|---|
| >18 wks | 2,352 | 3,234 | 1,388 | 2,352 | 1,388 | 3,426 | 3,234 | 1,871 |
| 10-18 wks | 674 | 192 | 964 | 674 | 1,355 | - | 192 | 1,363 |
| < 10 wks | 400 | - | 1,074 | 400 | 683 | - | - | 192 |

TC_3 and TC_4 have the deepest drawdowns and latest fills. These decrease the amount of flooding, and therefore have the best performance (i.e. most area flooded < 10 wks or 10-18 wks). TT_6 also appears to perform strongly, but this may be an artefact of the PM design, since it is insensitive to the timing of fill over the growing season; however, a dry spring is probably better than flooded in the spring then dried out in late summer.

The average number of hectares flooded for more than 18 weeks was carried forward to the consequence table.

# PERFORMANCE MEASURE INFORMATION SHEET #12

## MID COLUMBIA RIVER: FISH HABITAT

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Fish Habitat/ Mid Columbia River | Average Functional Large River Habitat | km | Reports average length of river that is not inundated as a result of backwatering of Arrow Reservoir. Serves as a proxy for habitat availability and energy requirements for key fish species. | km |
| | White Sturgeon Larval Habitat Availability | km | Reports on potential sturgeon larval habitat based on exceeding a velocity of 0.5 m/s during the sturgeon larval rearing period (15 July – 30 August) | Unreliable |

## Description

Discharge from Revelstoke Dam undergoes extreme fluctuations over short time periods. It is not uncommon for discharge to drop to zero during the middle of the night when power demand is low. During the day, discharge can exceed 2100 $m^3$/sec with 5 turbines, and over 2500 $m^3$/sec if a $6^{th}$ turbine is operational. These short-term or diel variations in flow are potentially harmful to white sturgeon, bull trout, rainbow trout, sculpin and dace that use the mid Columbia River (MCR) downstream of Revelstoke Dam. Predicting the effects of changes in depth, velocity and habitat area on fish populations is highly uncertain and controversial. A simple conceptual model shows how these physical factors could influence the somatic growth and survival rates of fish populations in the river (Figure 1). Diel variation in flow influences the inundation frequency of substrates at different elevations and very likely affects the productivity of lower trophic levels that provide food for fish. Previous efforts to find benthic invertebrates in the MCR for stable isotope analysis had limited success (D. Hunter, BC Hydro, Burnaby BC, pers. comm.); there is little doubt that the fluctuating flows in the MCR severely limit benthic invertebrate abundance, although the highly armoured riverbed could become a limiting factor if flow fluctuations were reduced. Higher discharges will increase the amount of wetted area by increasing river width, but this area may not be useable or of lesser value if velocities are very high, or if velocities and depths fluctuate over short time periods. These fluctuations increase energy expenditure because fish must constantly be moving to find suitable depth and velocity conditions. This movement also increases predation risk, especially for juvenile and small fish.

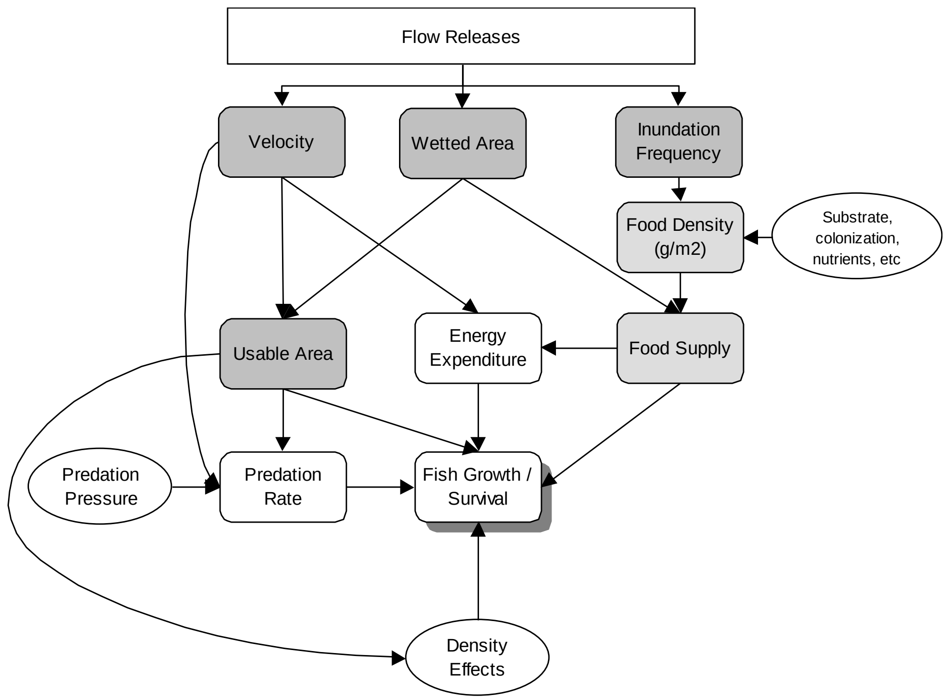



**Figure 1. Conceptual Model of the Potential Relationships between Physical Factors affected by Discharge from Revelstoke Dam and Important Processes affecting Fish Populations in the MCR**

WUP and Revelstoke $5^{th}$ and $6^{th}$ turbine additions were based on four performance metrics developed to account for the dynamics of these hypotheses. Functional river length is computed as a measure of the average annual minimum length of large river habitat that is functional downstream of Revelstoke Dam. The average maximum daily velocity difference over the month was computed as a measure of potential energy expenditure and predation risk. The amount of productive habitat, defined as the area of substrate that is continuously submerged for more than 21 days, was computed as an index of the response of lower trophic levels (algae and benthic invertebrates) to flow variation. In addition, an index of sturgeon spawning habitat suitability was computed, as sturgeon are known to spawn near the confluence of the Jordan River in the MCR.

These four PMs required modification for the Columbia River Treaty assessment. Sturgeon spawning surveys have documented spawning in the Revelstoke Reach (near Jordan River) in six years since 1999 (Hildebrand 2012). These results may indicate that flow may not be limiting sturgeon spawning conditions as assumed in the original PM calculation described above. The white sturgeon recovery group currently hypothesizes that flow may be more limiting for larval sturgeon. We adapted the sturgeon PM to reflect this change in thinking. The maximum daily velocity difference, and productive invertebrate habitat PMs require bi-hourly estimates of discharge from Revelstoke Dam from the GOM model. However, because GOM output was not available for CRT scenarios, simplifying assumptions were made. We modified the large river habitat PM to account for limitations in the GOM data.

## Calculations

The computation of MCR fish habitat performance measures in the Revelstoke Reach of Arrow Reservoir is based on results from the HEC-RAS 1-dimensional (1D) backwater hydraulic model. HEC-RAS is the official software released by the U.S. Army Corps of Engineers to perform both steady- and unsteady-state flow analyses in a river system. Such 1D hydraulic models are commonly used to predict the effects of discharge on wetted width, depth and average velocity at individual cross sections. The relationships between discharge and width, depth and velocity at particular cross-sections are referred to as hydraulic geometry. The effects of backwatering are considered in the HEC-RAS model, which is important as Arrow Reservoir water surface elevations have a large influence on width, depth, and velocity in the MCR.

The HEC-RAS model was run under a large range of discharges and downstream boundary conditions (Arrow Reservoir elevations) to generate a series of lookup-tables for water elevation, wetted width and average cross-sectional velocity. Flow scenarios for the CRT analysis consist of mean monthly predictions of discharge from Revestoke Dam, end-of-month elevations for Arrow Lakes, and mean local inflow to Arrow Lakes. These data were interpolated to weekly values for the CRT period of record (1928-1999). We also obtained weekly estimates of maximum flow from Revelstoke Dam from a GOM model run from 1964-1973. To determine the most appropriate maximum discharge to use in our CRT analysis (for each week in each year), we used the GOM prediction for that week with an average monthly discharge closest to the value from the CRT analysis.

Predicted flow and elevation estimates for each CRT timestep (weekly from 1928-1999) for each scenario are used to find the appropriate water surface, width, and velocity estimates in the lookup tables for all cross-sections for each time step. These values are then used to compute functional river length and sturgeon larval habitat PMs.

Predictions of discharge at each cross-section for each time period form the basis of the computations. Discharges at each cross-section are based on the maximum Revelstoke Dam discharge (as described above) plus the local inflows that are added at particular locations downstream of the dam. That is, the flow throughout the MCR varies spatially due to local inflows, but not temporally. In reality, even in the absence of local inflows, the discharge at an upstream cross-section at a particular time will be different than the discharge at a downstream location at that same time if releases from the dam are not constant. This temporal variation in discharge among cross-sections (unsteady flow) is controlled by the travel time of the discharge wave and the extent to which the wave gets attenuated.

The HEC-RAS model was developed from 245 cross-sections of the mid Columbia River from Revelstoke Dam to below the confluence of the Akolkolex River (about 37 km). The model was run under all combinations of 20 reservoir elevations ranging from 422-441 m.s.l. and 29 discharges ranging from 1-2832 $m^3$/sec. For each of these 580 runs, the predicted water surface elevation, wetted width and average velocity was saved for each of the 245 cross-sections. Lookup tables for each of these parameters consisted of 245 columns for the cross-sections and 580 rows for all the combinations of discharge and reservoir elevation.

Discharge at a cross-section is computed by,

$$Q_{cx} = Q_{\mathrm{Re}v} + Q_{Leak} + Q_{local} * Drain_{cx} \qquad [1]$$

where, $Q_{cx}$ is the discharge at cross-section 'CX', $Q_{Rev}$ is the total discharge released from Revelstoke Dam, $Q_{Leak}$ is the assumed leakage from all components of the dam (assumed to be constant 300 $ft^3$/sec or 8 $m^3$/sec, L. Hildebrand, Golder and Associates, Castlegar, BC, pers. comm.), $Q_{local}$ is the total local inflow to Arrow Reservoir, and $Drain_{cx}$ is the cumulative proportion of the local Arrow Reservoir watershed draining into cross-section 'CX'.

Historical inflows show strong seasonality, which is driven by snowmelt. Local inflows used in the scenario analysis correspond to inflows estimated for the CRT analysis period of record (1928-1999).

The computations for the aquatic performance measures for the MCR are described below.

**Functional River Length**

We used GOM estimates of the maximum discharge from Revelstoke Dam across 10 years under current operating regimes to approximate maximum flows under CRT scenarios for each model year (1928-1999) and week. To do this, BC Hydro provided maximum predicted flows for each week for 10 years from 1964-1973 from the GOM model and the associated average monthly flow from the dam. As our model cycled through each model year and week, we used the average monthly flow release from Revelstoke Dam to find the nearest match in the 10 year GOM record, and used the maximum flow predicted by GOM for that week in equation 1.

The average cross-sectional velocity for each day at each cross-section given flow and reservoir elevations is computed. The distance between each cross-section is considered to be functional river if the average velocity exceeds a minimum criterion of 0.2 m/sec. The sum of those functional lengths is the functional length of river for each week.The average functional length over year is then computed by summing the weekly values and dividing by 52, so that the PM predicts the average functional river length for the year.

**Sturgeon Larval Rearing Habitat**

A small subset of HEC-RAS cross-sections located from 1 km downstream of the Highway 1 Bridge to Jordan River (CX's 164-177) were used to model the hydraulic geometry in the area that is used by larval white sturgeon for rearing. Predictions of the cross-sectional average velocity for each weekly timestep, were computed for each cross-section using the HEC model based on local inflows and discharge from estimates of maximum discharge from Revelstoke Dam and Arrow Lakes elevation. These estimates were compared to a minimum suitable velocity of 0.5 m/sec (B. Green, pers. comm), and available habitat (distance between cross-sections) was summed if the velocity exceeded this criteria. These calculations were only conducted during the larval rearing period, which was assumed to range from July 15 to – August 30. The PM computes the average length of available sturgeon rearing habitat during this critical period for each year.

Predictions for this PM should be considered highly uncertain for a number of reasons. First, we compare a cross-section average velocity to 0.5 m/s criteria. As larval sturgeon live in or on the river substrate during this period of their life history, it would be much more appropriate to use a bottom velocity, rather than cross-sectional average velocity in the computations. However, the HEC model only provides average estimates. Bottom velocities would be much slower than average velocities due to drag of the substrate, thus our use of average velocities likely overestimates the amount of suitable rearing habitat. Second, the 0.5 m/s criteria is highly uncertain. Third, our model does not account for the amount of time within a week that the criteria is exceeded. Our calculations are based on the maximum discharge from Revelstoke Dam, and do not account for the fact that there may be large periods during the week when flows are much less than maximum values. We could not address this issue because bi-hourly GOM flow estimates were not available for all scenarios. Our PM value therefore represents the maximum amount of larval habitat, and not the time-integrated amount.

## Results

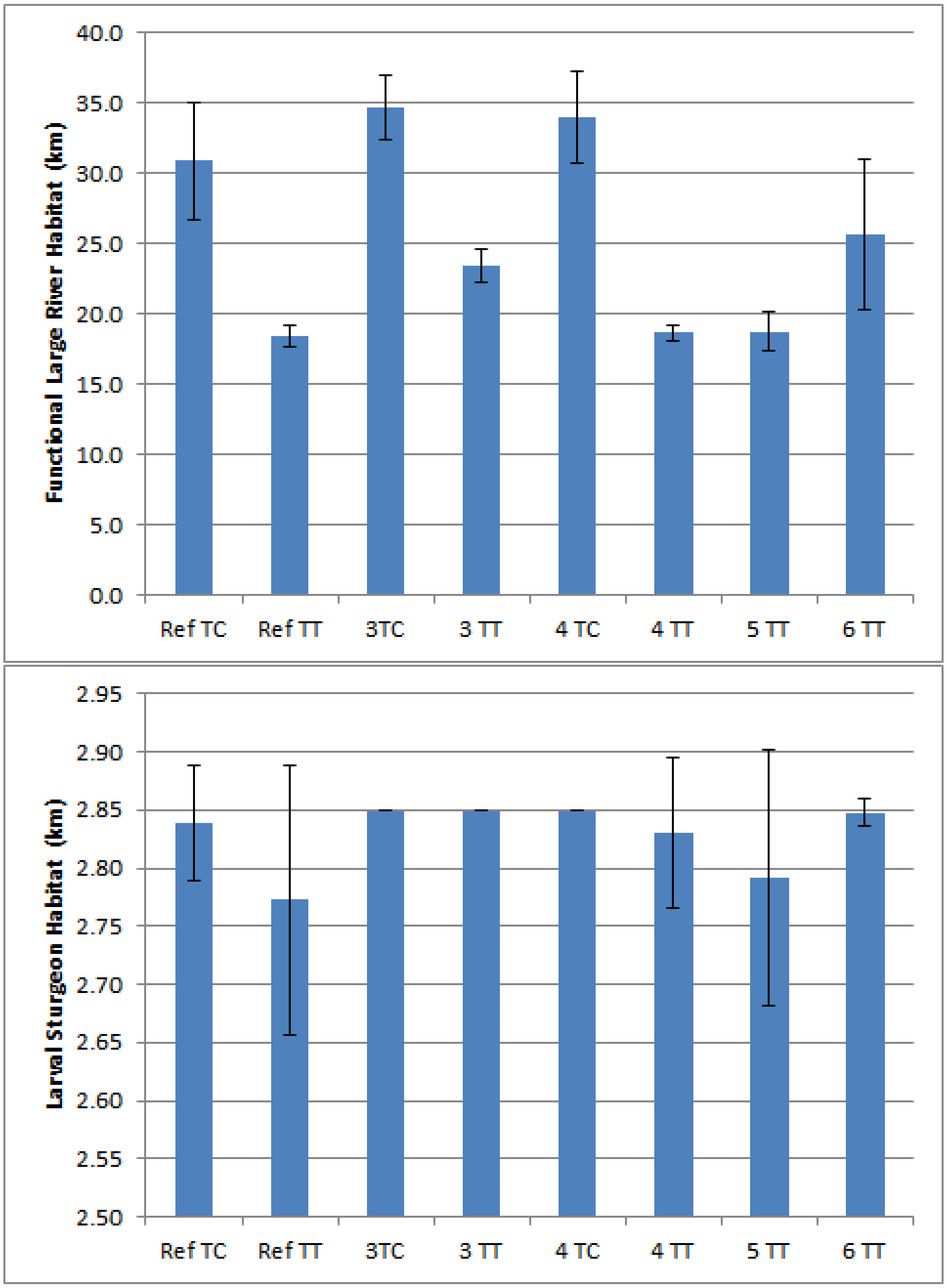
The average amount of function river habitat and larval sturgeon habitat across years for each scenario is summarized in Table 1, and presented graphically in Figure 1. Error bars in Figure 1 represent the extent of variation in PM predictions across years. These results indicate that there is a slight increase in functional river habitat for TC_3A and TC_4 scenarios relative to the base case (TC_Ref) because of lower reservoir levels. Reduced functional river length is seen for all TT scenarios except TT_6 because reservoir levels are higher.

The larval sturgeon habitat PM was very similar across all scenarios. Note that the total length between the cross-sections used in this analysis was 2.85 km. The average larval habitat length was at or very close to this maximum value for all scenarios except TT_5 (2.79 km) and TT_Ref (2.77 km). This, the results indicate that at maximum flows from Revelstoke Dam, the average velocity at the modelled cross-sections always exceeds the 0.5 m/s criteria. As pointed out in the description of the PM, this result likely underestimates the effects of operations on larval habitat because it does not use bottom velocities  to compare to the 0.5 m/s criteria (which would be lower) or account for the fact that flows from Revelstoke Dam can be considerably less than the maximum GOM values used here. Due to nonlinearities in the response of velocity to flow and lake elevations, there is no support for the assumption that relative differences in PM results among scenarios are accurate. At the same time, it is recognized that this performance measure was initially designed for looking at different operations and minimum flows at Revelstoke. The same Revelstoke constraints are applied in all the CRT alternatives so this performance measure is not expected to provide value in differentiating between the different scenarios. .

**Table 1.** Mean large river and larval sturgeon habitat across years for each CRT scenario.

| | Functoinal Large River Habitat (km) | Larval Sturgeon Habitat (km) |
|---|---|---|
| Ref TC | 30.9 | 2.84 |
| Ref TT | 18.4 | 2.77 |
| 3TC | 34.7 | 2.85 |
| 3 TT | 23.4 | 2.85 |
| 4 TC | 33.9 | 2.85 |
| 4 TT | 18.6 | 2.83 |
| 5 TT | 18.8 | 2.79 |
| 6 TT | 25.7 | 2.85 |

**Figure 1.** Trends in functional rive habitat length (top) and larval sturgeon habitat length (bottom) across CRT scenarios. Bar heights represent the multi-year average values, and error bars denote the 95% confidence interval which reflects inter-annual variation in PM values.




## References

Hildebrand, L. 2012. Effects of REV6 flows on white sturgeon spawning and early rearing habitat. Memo prepared by Golder and Associates to Laruen Cherzekoff, BC Hydro.

# PERFORMANCE MEASURE INFORMATION SHEET #13

## ARROW LAKES RESERVOIR: WILDLIFE

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Wildlife/ Arrow Lakes Reservoir | Nesting Birds | % nesting habitat availability | A measure of the percent of habitat that is not inundated during the nesting season | 3% |
| | Fall Migrating Birds | % migratory habitat availability | A measure of the percent of habitat that is not inundated during the fall migration season | 4% |

## Description

The Revelstoke Wetlands is unique in that it comprises the largest known area of waterbird habitat within the impounded waters of the Columbia River. It provides important wetland habitat for 213 birds species (84 species of waterbirds, 21 birds of prey, and 108 species of land birds), as well as habitat for migratory, breeding and wintering birds, important breeding habitat for the painted turtle and short tailed weasels, and important wintering habitat for ungulates.

The spatial extent, timing and duration of flooding of the Revelstoke Reach of the Arrow Lakes Reservoir are important factors that determine habitat availability and nesting success for birds utilizing this reach. As part of the Columbia River Water Use Planning (WUP) process, a series of models were developed to determine how various operating strategies affect birds in the Revelstoke Reach. A simple metric was initially developed to track the frequency (number of days) at which an operating alternative met preferred conditions for Revelstoke Wetlands to function as a migratory bird stopover. More detailed bird habitat performance measures were subsequently developed to estimate available habitat for a range of migratory shorebirds and breeding birds in Revelstoke Reach.

## Performance Measures

A set of parameters was used for modelling the impacts of nest inundation, and calculating habitat availability in the early fall. These were subsequently modified during the Revelstoke 5 and Mica 5/6 environmental assessment processes. These are summarized below.

**Parameters for Nesting and Fall Migration Habitat Use**

| | Grassland Nesting Waterfowl | Late Nesting Waterfowl | Ground Nesting Landbirds | Shrub Nesting Landbirds | Short-Eared Owls | Land Bird Migration | Shorebird Fall Migration | Waterfowl Migration |
|---|---|---|---|---|---|---|---|---|
| Start Nest Date | 15 Mar | 14 May | 14 May | 14 May | 30 Apr | 25 Jul | Jul 20 | Sep 1 |
| End Nest Date | 18 Jun | 16 Jul | 16 Jul | 30 Jul | 16 Jul | 30 Sep | Sep 15 | Nov 15 |
| Peak Nest Date | 5 Apr | 1 Jun | 4 Jun | 10 Jun | 28 May | 28 Aug | Aug 15 | Oct 15 |
| Fledge Time (weeks) | 9 | 9 | 6 | 6 | 11 | n/a | n/a | n/a |
| Lower Elevation Range (metre) | 434 | 435 | 434 | 436 | 437 | 432 | 434 | 432 |
| Upper Elevation Range (metre) | 440 | 439 | 439 | 440 | 439 | 440 | 439 | 440 |

## Calculations

The most recent version of the HEC-RAS model for the mid Columbia River was used to estimate water surface elevations throughout the Revelstoke Reach. (Refer to the Mid Columbia River Fish Habitat PM Sheet for a description of the HEC-RAS model).The model is driven by Arrow Reservoir elevations (at Fauquier), discharge from Revelstoke Dam, and estimated local inflows. Water surface elevations are predicted for every week of the year from 1964 to 1973 based on the average local inflow by week, the average reservoir elevation by week, and the minimum or maximum hourly discharge from Revelstoke Dam by week. In this analysis, the maximum hourly discharge is used.

The effects of water surface elevation on bird populations in the Revelstoke Reach of Arrow Reservoir are modeled by predicting nesting success or useable habitat area. Model calculations can be summarized in the following five steps:

1) Nest and fledge parameters for specific groups of birds determine the fraction of nests created per week and the period when nests are vulnerable to flooding, respectively. In the case of migratory (non-nesting) bird groups, the parameters determine the timing of habitat use.
2) Nests are distributed over a defined elevation range, in proportion to the habitat area at each cross section – elevation category (in 0.25 m increments).
3) Average reservoir surface elevation and maximum weekly discharge are used in HEC-model to determine water surface elevation at each cross-section for each week of simulation.
4) Water surfaces are compared to elevation bands over which birds are distributed to determine which bands are flooded on each week.
5) Habitat availability or nest loss is computed from 4) and tallied by year. The model is run for eight different bird groups with different nest and fledge timing parameters and different elevation distributions. This statistic captures both nest loss due to flooding and overall loss of habitat (prior to nests being built).

The model also computes habitat availability for migratory birds that do not nest in the area (migratory landbirds, shorebirds, and waterfowl). The performance metric in these cases is driven only by the extent of unflooded area relative to the timing of migration, and not by loss of nests.

## Key Assumptions and Uncertainties

- Each alternative is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1929-1999).
- The seasons of use, preferred elevation bands are correct for each of the bird groups.
- Assumes that there is no plasticity in nest site selection. If an area is flooded when a breeding pair arrives, the simulation predicts that the birds do not successfully reproduce, rather than moving upslope to dry terrain. This dynamic results in very low survival rates relative to what likely occurs. However, the metric does provide an index of habitat loss, which could have population-level effects due to density dependent processes (e.g., poorer nesting sites are selected at higher densities leading to reduced reproductive success).

## Results

Table 1 shows the average percent nest survival for eight groups of birds. The table is formatted across a colour spectrum from deep green (highest survival) to deep red (lowest survival). Figure 1 plots these data as bar charts.

**Table 1 – Average Nest Survival (% surviving) for 8 Bird Groups.**

| | TC_Ref | TT_Ref | TC_3A | TT_3A | TC_4 | TT_4 | TT_5 | TT_6 |
|---|---|---|---|---|---|---|---|---|
| Grassland Nesting Waterfowl | 32.1 | 2.0 | 74.6 | 37.1 | 70.8 | 1.5 | 1.9 | 0.5 |
| Ground Nesting Landbirds | 6.2 | 0.0 | 48.7 | 24.6 | 45.2 | 0.0 | 1.7 | 29.5 |
| Landbird Migration | 19.2 | 1.4 | 37.7 | 13.6 | 31.2 | 1.1 | 1.5 | 63.1 |
| Late Nesting Waterfowl | 6.7 | 0.0 | 57.5 | 26.8 | 49.7 | 0.0 | 0.4 | 23.1 |
| Shorebird Fall Migration | 20.4 | 0.0 | 47.5 | 16.5 | 40.1 | 0.0 | 0.2 | 70.2 |
| Short-Eared Owls | 14.7 | 0.0 | 87.3 | 55.4 | 71.1 | 0.0 | 0.1 | 33.6 |
| Shrub Nesting Landbirds | 17.6 | 3.2 | 80.0 | 55.9 | 70.9 | 1.9 | 8.8 | 45.5 |
| Waterfowl migration | 25.9 | 1.3 | 36.2 | 1.3 | 26.5 | 1.2 | 1.3 | 51.8 |

**Figure 1. Average Nest Survival (% surviving) for 8 Bird Groups.**


As per the NTSA process data for short-eared owls is considered representative of nesting birds, and Shorebird Fall migration are used to represent migratory birds in the consequence table.

Birds that nest in spring or use the area in the spring (first 5 plots from grassland nesting waterfowl to short-eared owls) do much better under TC_3 and TC_4. Birds that use the reservoir in late summer and fall (the 'migration' groups) do best under TT_6 where the reservoir is drawn down in late summer.

# PERFORMANCE MEASURE INFORMATION SHEET #15

## ARROW LAKES RESERVOIR: NAVIGATION

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Navigation/ Arrow Lakes Reservoir | Navigability | 1) # days elevation is greater than 1415 ft between 1 January and 15 April | Reports # of days that the reservoir water level allows for log transport through the Narrows | 7 days |
| | | 2) Weighted-Days (by season and elevation) | | |

## Description

Commercial operations (primarily local forest companies) can be affected by reservoir elevations. Either low or high reservoir elevations can result in a disruption to operations. When reservoir levels do not fall within critical elevations, forest companies respond by changing sites or routes, altering equipment, breaking down log rafts, and/or by delaying logging or transport operations, all of which increase costs.

The primary concern related to commercial navigation in Arrow Lakes Reservoir is periods of low water levels when transport of log rafts through the Narrows is impeded. It is reported that when the reservoir is above 1420 ft, Celgar is able to tow 16+ rafts through the area[1]. However, when the reservoir is between 1415 and 1420 ft, Celgar is required to respond by breaking down the rafts in sizes capable of making it through the Narrows. This is further impeded at reservoir levels between 1410 and 1415 ft.

A key constraint for log transport is water levels during the winter period (Jan 1- Apr 15). Reservoir water levels are generally high enough to facilitate log transport operations during the June to December period, although there are occasions when the reservoir elevation is below the optimal level. Log transport operations typically do not occur between April 15 and June 1; however, if logging operations continue into this period, Celgar generally responds to lower reservoir water levels by either storing the logs in staging areas and waiting for higher levels or breaking down the rafts.

Breaking the log rafts down into smaller rafts requires additional tows and reassembly on the downstream side of the Narrows. This increases the time required and therefore the overall cost of log transport operations on Arrow Lakes Reservoir. Operations north of Burton are generally shut down when reservoir water levels are drafted below 1415 ft.

**Note**: As specified in the Local Operating Order, BC Hydro maintains a minimum discharge of 10 kcfs year round from Arrow Lakes Reservoir to facilitate log transport operations below HLK Dam. As for the NTSA,as this has been built into the assumptions of the modelling for this evaluation, a performance measure was not developed for commercial navigation in the lower Columbia River.

[1] Email correspondence from Mike Lynn, Celgar to BC Hydro

## Performance Measures

The objective of maintaining navigability through the Narrow for the log transport operations was not considered during the Columbia Water Use Plan process. As with the NTSA process, as a result, no performance measure was developed, and there are no former methods and models to apply to evaluate the alternativesBased on input from the Celgar representative during the NTSA process, two separate parameters were developed for this analysis.

### Parameter 1

The first parameter mimics the approach used for the Arrow Soft Constraints by simply focusing on a key season and elevation threshold. From the above description, the key season selected is Jan 1- April 15, and a key elevation threshold selected is 1415 ft.

### Parameter 2

The second parameter applies weights to both elevations and seasons to reflect the overall performance across the entire year. From the description above, the following logic is used to derive the weights:

1. Elevation weighting factors: Above 1420 weight = 1, below 1410 weight = 0, and each meter in between is scaled between these two points (i.e., 1419 is 0.9).
2. Seasonal weighting factors: Peak operational seasons weight = 1 (Jan 1 – Apr 15, and Jun 2 - Dec 31); Spring season weight = 0.25.

Elevation and seasonal weights are then multiplied together to develop a combined weighting factor (Table 1).

**Table 1. Selection of Navigation Weighting Factors by Elevation and Season[1]**

| | | | Seasonal Weight | | |
|---|---|---|---|---|---|
| | | | Jan-01 Apr-15 | Apr-16 Jun-01 | Jun-02 Dec-31 |
| | | | 1 | 0.25 | 1 |
| Elevation Weight | Above 1420 | 1 | 1.0 | 0.25 | 1.0 |
| | above 1415 | 0.5 | 0.5 | 0.125 | 0.5 |
| | Below 1410 | 0 | 0.0 | 0.0 | 0.0 |

1 Weighting factors are interpolated for each week and each metre elevation band

## Calculations

For each alternative:

1. Assemble the daily simulated results for reservoir elevations over 60 years (derived from HYSIM 1929-1999; Figure 1) for each alternative.
2. Parameter (1): Count the number of days between January 1 and April 15 when the reservoir elevation is greater than 1415 ft.
3. Parameter (2): Calculate the annual Weighted-Day by sampling each day against the combined weighting factors (Table 1) and summing over the year.
4. Summarize all statistics (Figures 2 and 3).

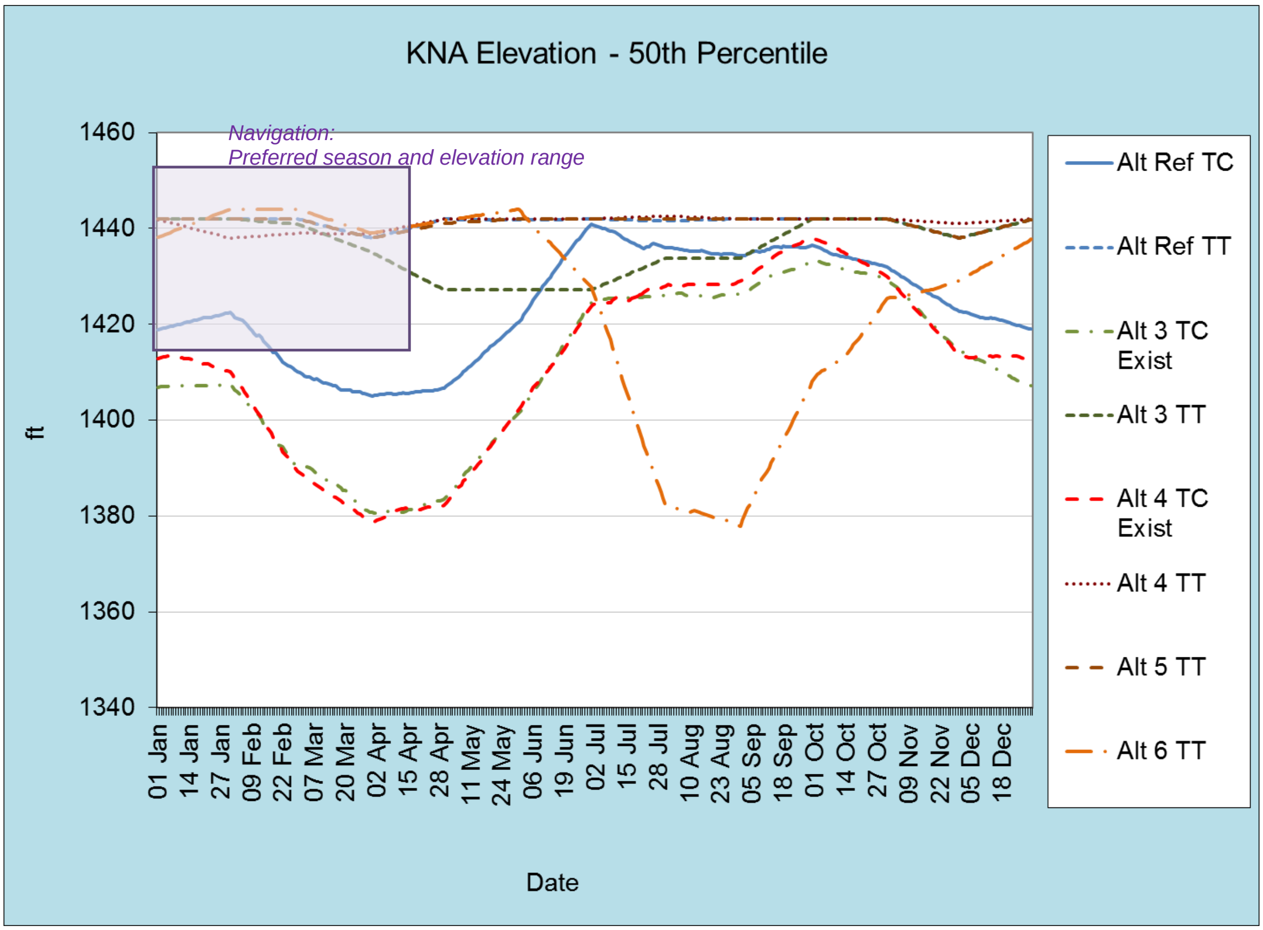


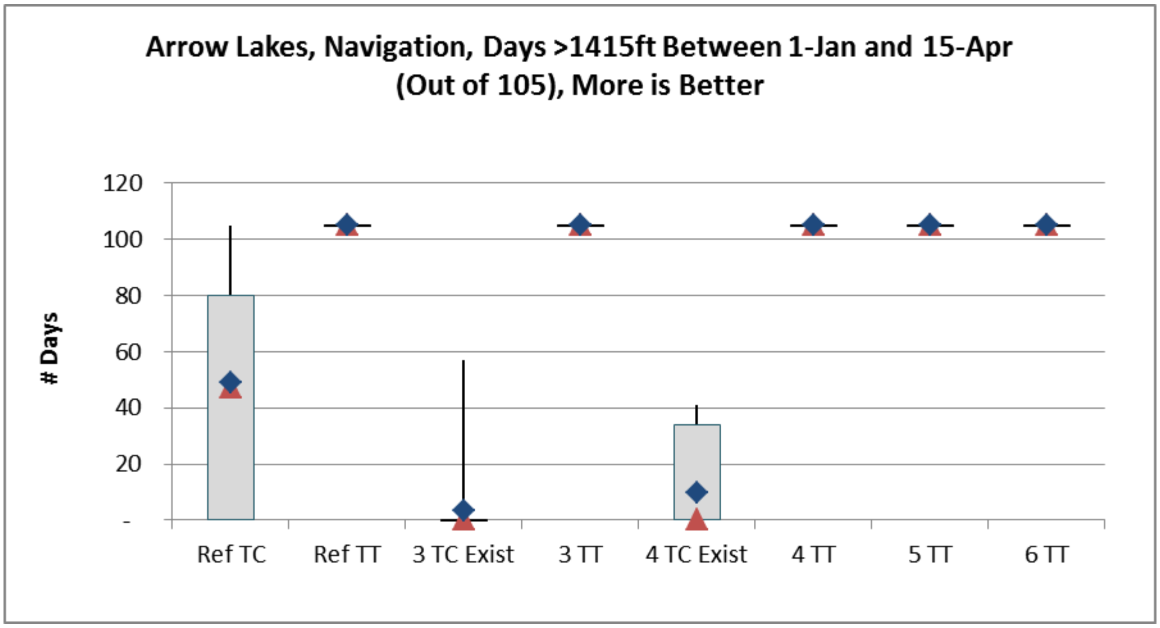

**Figure 1. HYSIM Simulated Arrow Lakes Reservoir elevations. Median over 60 years showing the preferred elevation ranges for commercial navigation**

## Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows.
- Assumes that the weightings applied to the preferred elevation ranges and operational seasons are accurate.

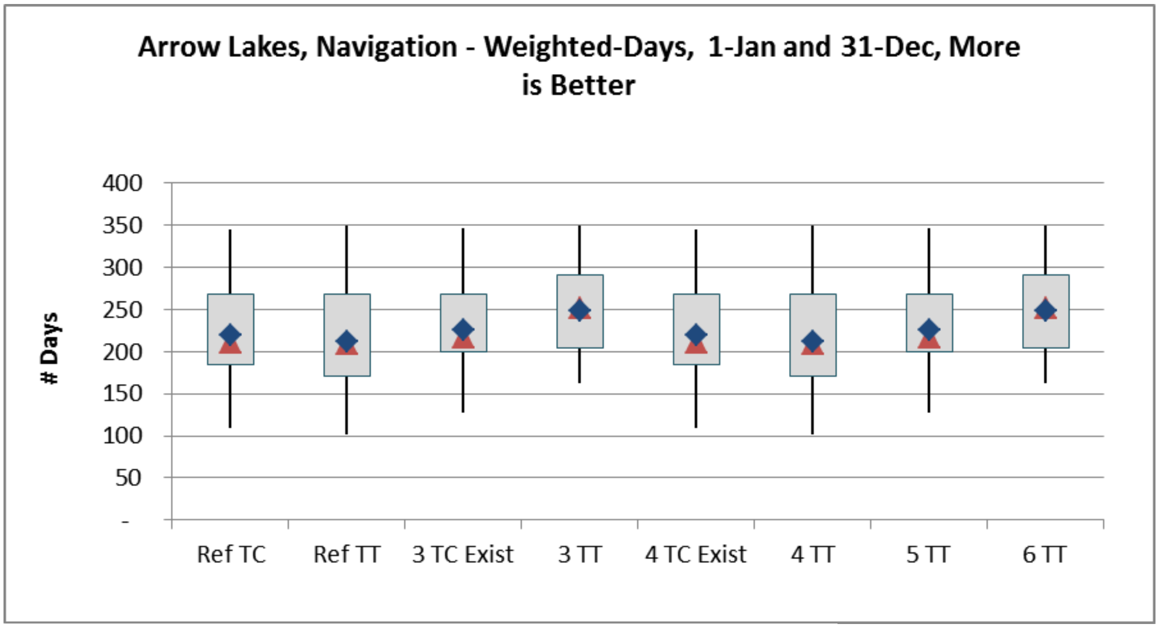
## Results

**Figure 2. Days above Preferred Elevation in Key Season –**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 105 | 105 | 57 | 105 | 41 | 105 | 105 | 105 | Max |
| 80 | 105 | - | 105 | 34 | 105 | 105 | 105 | 90th |
| 47 | 105 | - | 105 | - | 105 | 105 | 105 | Med |
| 49 | 105 | 3 | 105 | 10 | 105 | 105 | 105 | Mean |
| - | 105 | - | 105 | - | 105 | 105 | 105 | 10th |
| - | 105 | - | 105 | - | 105 | 105 | 105 | Min |

**Figure 3. Weighted-Days across Entire Year – HYSIM**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 346 | 349 | 347 | 349 | 346 | 349 | 347 | 349 | Max |
| 268 | 268 | 268 | 292 | 268 | 268 | 268 | 292 | 90th |
| 211 | 209 | 217 | 252 | 211 | 209 | 217 | 252 | Med |
| 219 | 211 | 226 | 248 | 219 | 211 | 226 | 248 | Mean |
| 184 | 170 | 200 | 204 | 184 | 170 | 200 | 204 | 10th |
| 109 | 102 | 127 | 163 | 109 | 102 | 127 | 163 | Min |

# PERFORMANCE MEASURE INFORMATION SHEET #16

## ARROW LAKES RESERVOIR: RECREATION

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Recreation/Arrow Lakes Reservoir | Access Days | 1) # Access Days by Activity<br>2) # Access Days – All Activities<br>3) Weighted-Days – All Activities | Reports # of weighted days that the reservoir water level is within the preferred ranges during the key shore-based and water-based recreation seasons | 7 days |

## Description

Arrow Lakes Reservoir provides for a variety of recreational opportunities. The most popular activities include fishing, boating and day use (swimming and picnicking). Recreation use by both residents and tourists is increasing and will likely be enhanced by the provision of additional water-based facilities. Several boat ramp improvement projects are currently underway as part of BC Hydro's Water Licence Requirement Program, including construction of new ramps at Burton and Anderson Point and upgrades to existing ramps at Fauquier, MacDonald Creek and Edgewood.

Recreation access and associated benefits are important in Arrow Lakes Reservoir. Local communities benefit from improvements to the quality and diversity of recreation and tourism experiences through a greater quality of life, as well as through local economic development benefits that result from increased usage. A number of key factors that affect recreational quality and use include:

- Diversity and abundance of fish and wildlife, since many recreational activities are focused on enjoyment of these natural resources
- Ability to safely access the water or shorelines for water-based and shore-based activities
- Visual quality of viewscapes (appearance of the reservoir related to avoidance of exposed mudflats/dust and exposed standing debris)
- Avoidance of navigational hazards associated with standing debris

During the Columbia WUP process, it was agreed that boat access and shoreline access would capture most recreational interests. For boat access, the Recreation Technical Subcommittee identified preferred elevations over the recreation season that would provide "good opportunity" for a broad range of interests, including access via boat ramps, usability of boat ramps and quality of boating within that range of elevations. The boat access measure was not tied directly to physical structures (i.e., boat ramps). The shoreline access measure was defined around a range of elevations that constituted "good opportunity" for shore-based activities, with activities decreasing in frequency when the water is above or below this elevational zone. Again, this measure was not tied to site-specific elevation issues.

## Performance Measures

There are multiple ways to measure recreation performance. In addition to the Soft Constraint that is reported in a separate PM Information Sheet, three additional approaches are presented below for consideration.

**Approach 1**

The first approach is based on critical water level ranges for water-based activities (boat access) and shore-based activities, as summarized in RL&L (2001). This approach, which was used in the Columbia WUP, calculates separate measures for boat access and shoreline access using the parameters defined in Table 1.

**Table 1. Parameters for Boat Access and Shoreline Access from RL&L (2001)**

| Area | Measure | Dates | Critical Elevation Zone | MSIC |
|---|---|---|---|---|
| Arrow Lakes Reservoir | Boat Access Days | 01 May to 30 Sept | # days between 1435 – 1444 ft | 7 days |
| | Shoreline Access Days | 01 May to 30 Sept | # days between 1425 – 1435 ft | 7 days |

**Approach 2**

The second approach emerged from discussions during the NTSA process. The basic premise was that there is a range of overlap in the preferred elevation ranges across shore-based and water-based activities, and that a compromise definition may be possible. In developing the new approach (Table 2), it was noted that reaching full pool elevation was less desirable and that, given increases in property development and full-time residency, a wider seasonal definition would be appropriate (April 1 to October 15). This is illustrated in Figure 1.

**Table 2. Parameters for Overall Recreation Performance**

| Area | Measure | Dates | Critical Elevation Zone | MSIC |
|---|---|---|---|---|
| Arrow Lakes Reservoir | Recreation Days | 01 April to 15 October | # days between 1425 – 1440 ft | 7 days |

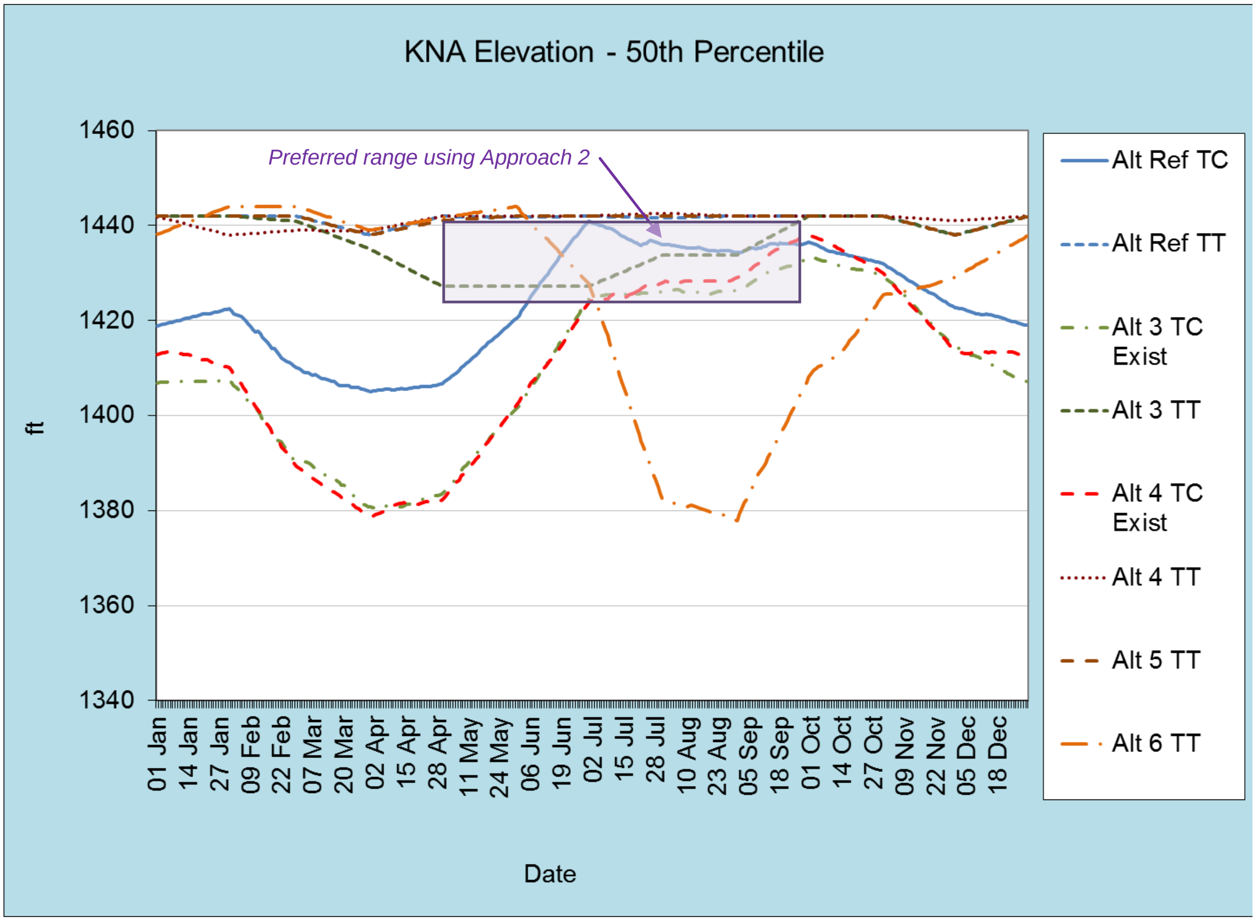



**Figure 1. Simulated Arrow Lakes Reservoir elevations. Median showing the preferred elevation ranges and season for boat access and shoreline access (Approach 2).**

**Approach 3**

The concept for the third approach also emerged from the NTSA process. Weights are applied to both elevations and seasons to reflect the overall performance across the entire year.

The following logic is used to derive the weights:

1. Elevation weighting factors: Between 1435 and 1440 weight = 1; Transition down to a weight = 0 at elevations above 1444; Transition down to weight = 0 at elevations below 1415.
2. Seasonal weighting factors: Peak recreation season weight = 1 (Jul 1 to Aug 31); Shoulder seasons transition down to weight = 0.1 (Apr 16 to Jun 30; Sep 1 to Oct 15); Off-peak seasons transition down to weight = 0 (Oct 16 to Dec 31; Jan 1 to Apr 15).

Elevation and seasonal weights are then multiplied together to develop a combined weighting factor (Table 3).

**Table 3. Selection of Recreation Weighting Factors by Elevation and Season[1]**

| | | | Seasonal Weight | | | | |
|---|---|---|---|---|---|---|---|
| | | | Jan-01 Apr-15 | Apr-16 Jun-30 | Jul-01 Aug-31 | Sep-01 Oct-15 | Oct-10 Dec-10 |
| | | | 0 to 0.1 | 0.1 to 1 | 1 | 1 to 0.1 | 0.1 to 0 |
| Elevation Weight | Above 1444 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1435 to 1440 | 1 | 0.05 | 0.5 | 1 | 0.5 | 0.1 |
| | above 1430 | 0.6 | 0.03 | 0.3 | 0.60 | 0.3 | 0.03 |
| | Below 1425 | 0.2 | 0.01 | 0.1 | 0.20 | 0.100 | 0.01 |
| | Below 1415 | 0 | 0 | 0 | 0 | 0 | 0 |

1 Weighting factors are interpolated for each week and each metre elevation band

There are a number of recreational activities that take place in the Arrow drawdown zone that may be directly linked to reservoir elevations (e.g., hiking, ATV use, cross country skiing), which have different preferred or optimal water levels. However, there is little systematic information on how fluctuating reservoir levels influence the recreation behaviour of these key user groups. As part of implementing the WUP, a recreational demand study is being implemented over a 5-year period (2009-2013). The results of this study should provide a better understanding of how reservoir water levels affect the quantity, quality and frequency of a broad range of water-based and shore-based recreation activities, and help to develop better performance measures that link aspects of recreation by local/tourist groups to reservoir levels for future operational decision-making.

## Calculations

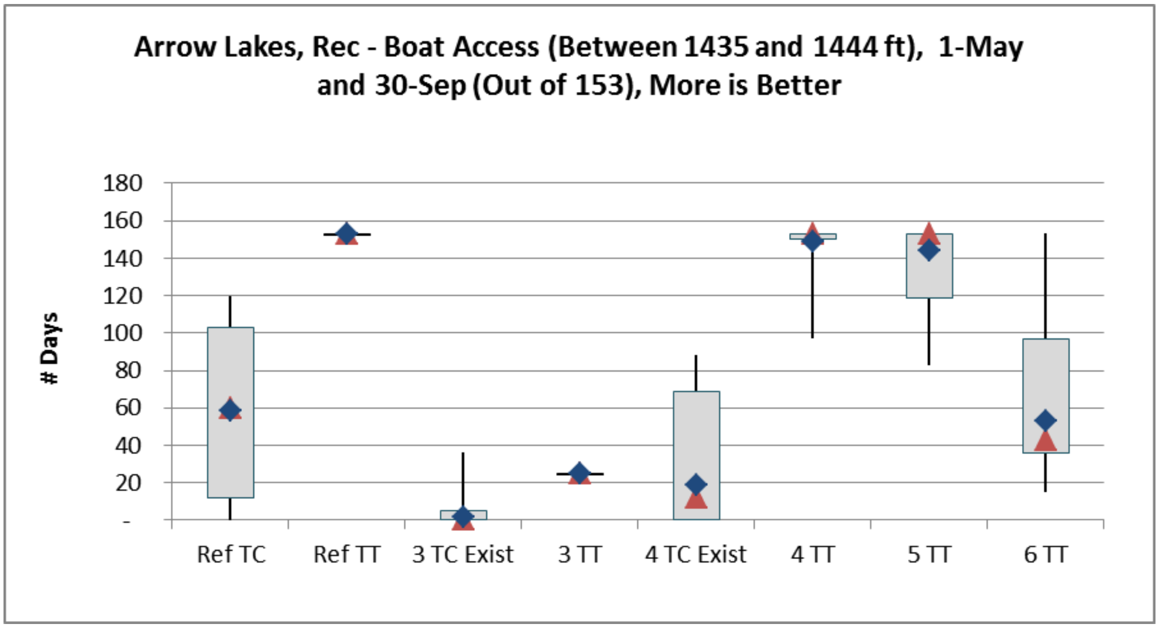
For each scenario:

1. Assemble the daily simulated results for reservoir elevations for each alternative.
2. Approach (1): Count the number of days between thresholds for boat access (1435 – 1444 ft) and shoreline access (1425 – 1435 ft) between 1 May and 30 Sept.
3. Approach (2): Count the number of days between thresholds for overall recreation (1425 – 1440 ft) between 1 April and 15 Oct.
4. Approach (3): Calculate the annual Weighted-Day by sampling each day against the combined weighting factors (Table 1) and summing over the year.
5. Summarize all statistics (Figures 2-4).

## Key Assumptions and Uncertainties

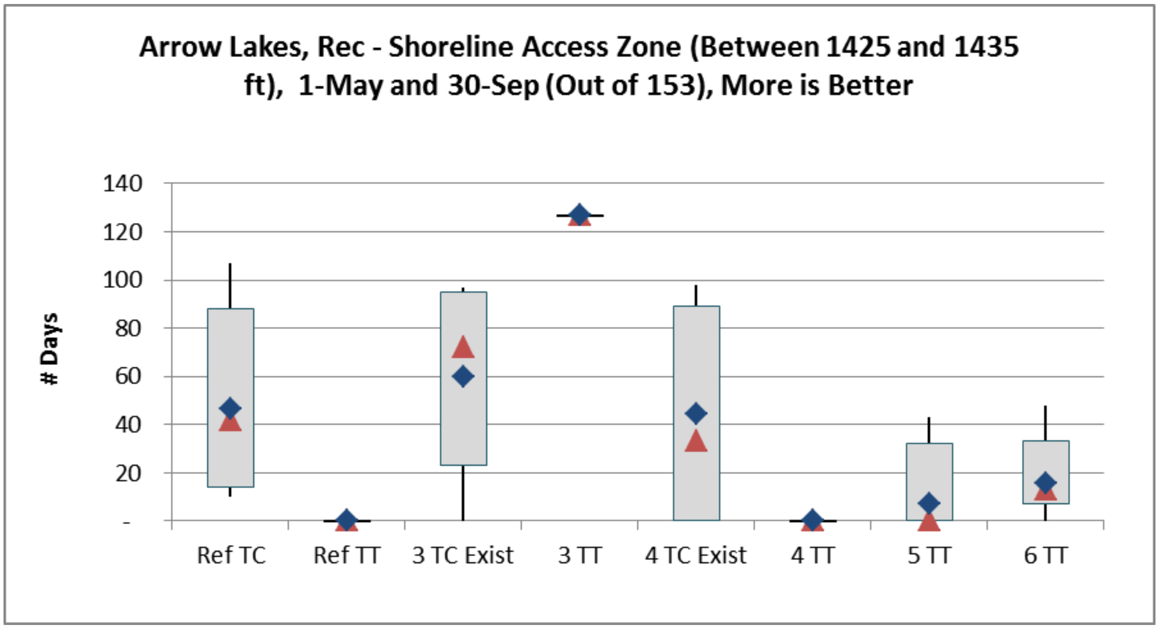
- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1929 – 1999).
- Assumes that there is minimal recreational use outside the defined recreation season.
- Assumes that the preferred season and elevations are accurate.
- There is uncertainty regarding which approach is best at capturing the essence of access issues for boating and shoreline use.

## Results




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 120 | 153 | 36 | 25 | 88 | 153 | 153 | 153 | Max |
| 103 | 153 | 5 | 25 | 69 | 153 | 153 | 97 | 90th |
| 60 | 153 | - | 25 | 12 | 153 | 153 | 43 | Med |
| 59 | 153 | 2 | 25 | 19 | 149 | 144 | 53 | Mean |
| 12 | 153 | - | 25 | - | 150 | 119 | 36 | 10th |
| - | 153 | - | 25 | - | 97 | 83 | 15 | Min |

**Figure 2. Approach 1 (a) Shoreline Access Days**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT |
|---|---|---|---|---|---|---|---|
| 107 | - | 97 | 127 | 98 | - | 43 | 48 |
| 88 | - | 95 | 127 | 89 | - | 32 | 33 |
| 42 | - | 72 | 127 | 33 | - | - | 13 |
| 47 | - | 60 | 127 | 44 | - | 7 | 16 |
| 14 | - | 23 | 127 | - | - | - | 7 |
| 10 | - | - | 127 | - | - | - | - |

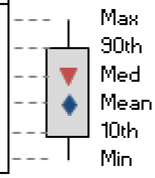
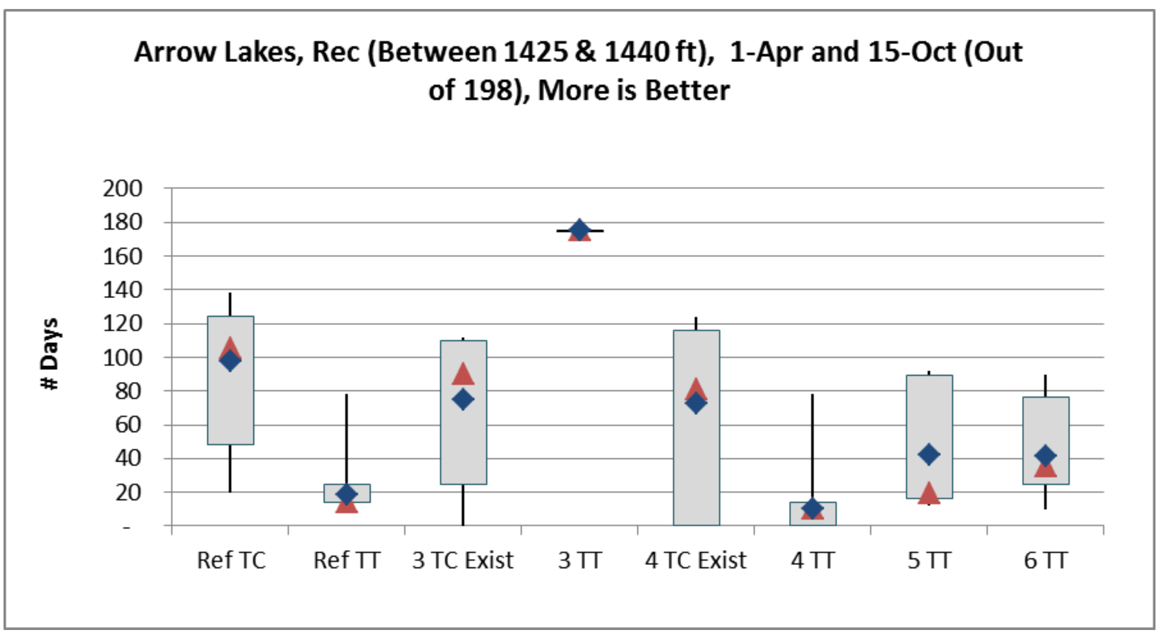
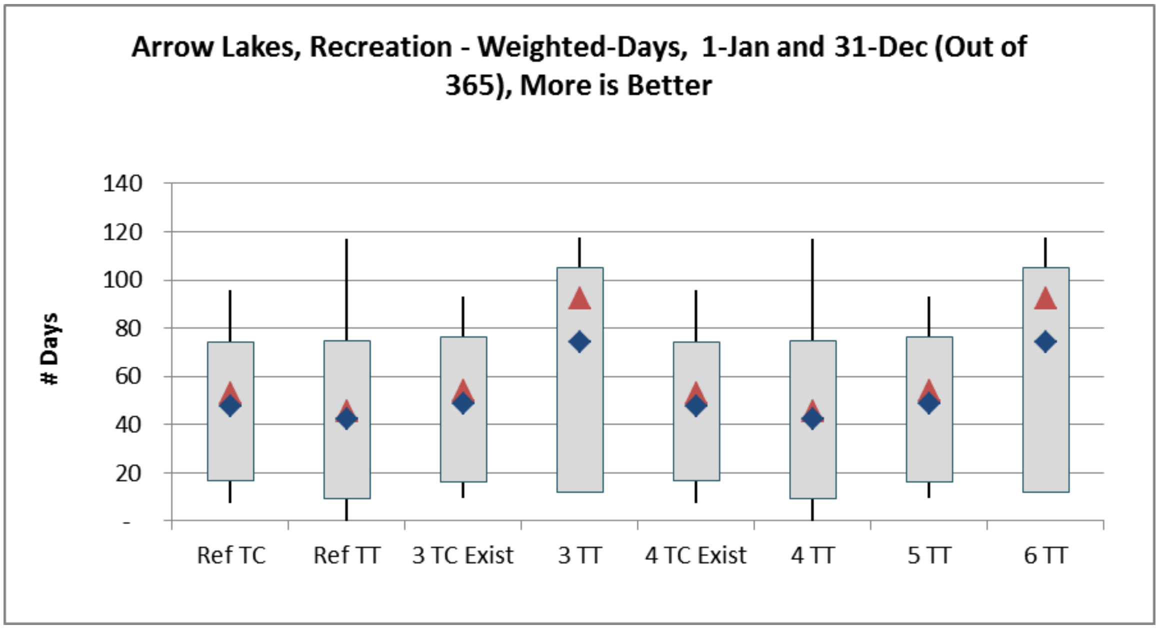



**Figure 3: Approach 1 (b) Shoreline Access Days**



| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 138 | 78 | 112 | 175 | 124 | 78 | 92 | 90 | Max |
| 124 | 25 | 110 | 175 | 116 | 14 | 89 | 76 | 90th |
| 105 | 14 | 90 | 175 | 81 | 10 | 19 | 35 | Med |
| 97 | 18 | 75 | 175 | 72 | 10 | 42 | 41 | Mean |
| 48 | 14 | 25 | 175 | - | - | 16 | 25 | 10th |
| 20 | 12 | - | 175 | - | - | 12 | 10 | Min |

**Figure 4. Approach 2 Combined Recreation Days**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 96 | 117 | 93 | 117 | 96 | 117 | 93 | 117 | Max |
| 74 | 75 | 76 | 105 | 74 | 75 | 76 | 105 | 90th |
| 53 | 45 | 54 | 93 | 53 | 45 | 54 | 93 | Med |
| 48 | 42 | 49 | 74 | 48 | 42 | 49 | 74 | Mean |
| 16 | 9 | 16 | 12 | 16 | 9 | 16 | 12 | 10th |
| 7 | 0 | 10 | 12 | 7 | 0 | 10 | 12 | Min |

**Figure 5. Approach 3 Weighted-Days**

**Use in CRTR consequence table:**

For the consequence table, a modified version of Approach 2 was carried forward to the consequence table. Each of the approaches show a mixed performance for the alternatives Alts Ref TT, 3 TT, 4 TT and 5 TT that keep the reservoir elevation high throughout the summer. As Figure 2 illustrates, this is because the models, being unconstrained for reservoir elevation, allowed the elevation to sit above the 1440' threshold. In reality, however, BC Hydro could hold each of these alternatives slightly below 1440' with an approximate $2million / yr power loss and with relatively small effects on other interests.

Rather than remodel each of these alternatives, it was decided to credit simply credit each of them with the maximum possible mean value for the recreation season.

Final results used are:

| Ref TC | Ref TT | 3TC | 3 TT | 4 TC | 4 TT | 5 TT | 6 TT |
|---|---|---|---|---|---|---|---|
| 97 | 197 | 75 | 197 | 72 | 197 | 197 | 41 |

## References

RL&L Environmental Services Ltd. 2001. Water Use Plans – Environmental information review and data gap analysis. Volumes 1 & 2. Prepared for BC Hydro, Burnaby by RL&L Environmental Services in association with Robertson Environmental Services Ltd., Pandion Ecological Research Ltd., Bruce Haggerstone Landscape Architect, Pomeroy & Neil Consulting Ltd. and DVH Consulting. RL&L Report No. 858V1-F.

# PERFORMANCE MEASURE INFORMATION SHEET #17

## ARROW LAKES RESERVOIR: CULTURE & HERITAGE

| Objective / Location | Performance Measure | Units | Description |
|---|---|---|---|
| Culture & Heritage / Arrow Lakes Reservoir | Archaeological Sites – Wave Erosion | Weighted-Days reservoir elevations are within sensitive elevation zones | Total number of weighted days that the reservoir is potentially eroding archaeological sites through wave action |

## Background

During the Columbia WUP process, it became apparent that there was a significant data gap regarding the number and condition of actively eroding archaeological sites in the drawdown zone of Arrow Lakes Reservoir. The content and significance of documented sites within the reservoir had not been comprehensively reviewed, and it is likely that additional undocumented archaeological sites exist in areas that have not been previously surveyed. Several concerns were expressed about the potential effects that physical works projects being implemented in the reservoir (i.e., wildlife habitat physical works, revegetation program, debris management and boat ramp improvement projects) could have on known and yet-to-be discovered archaeological sites. It was recognized that archaeological assessments would be required to ensure that the physical works projects are undertaken in a compatible manner with archaeological site protection requirements and that opportunities to incorporate archaeological site mitigation measures be considered in the design of these works.

As part of WUP implementation, a 2-year (2008-2009) archaeological overview was completed in Arrow Lakes Reservoir to identify and assess archaeological resource potential or sensitivity within portions of the drawdown zone. Over the two years of the study, a total of 26 new archaeological site locations were identified in Revelstoke Reach in areas proposed for revegetation, wildlife habitat physical works and bank erosion loci. Of this, 24 sites are considered to be of potentially high archaeological significance. Four of the newly discovered sites are situated in bank erosion loci identified as having potential to be affected by increased water level fluctuations associated with five-unit operations at Revelstoke Dam. Monitoring of these locations is being undertaken to better assess the potential effects of Revelstoke 5 flows on these archaeological resources. The 5-year erosion monitoring study was initiated in 2009 with the primary objective of quantitatively measuring the magnitude, severity, rate of change and estimated duration of erosion effects caused by reservoir operations on selected portions of escarpment and other significant landforms situated within the drawdown zone of the reservoir.

For the CRTR process, a total of 121 sites had been identified with associated elevation bands.

## Performance Measure

In developing a performance measure for evaluating the NTS scenarios, an inventory of archaeological sites in the vicinity of Arrow Lakes Reservoir was obtained from the Remote Access to Archaeological Data (RAAD) database of the Archaeology Branch. The archaeology sites extracted from RAAD were selected based on their proximity to the reservoir shoreline as displayed in RAAD.

Elevations for each site were interpolated using a digital elevation model of Arrow Lakes Reservoir, which was collected between 1414 ft and 1476 ft. A 3D terrain surface was generated from the digital elevation model, and the site polygons were draped over the terrain and the elevations were interpolated from the terrain surface heights. Some archaeology sites fell below or were beyond the DEM collection area, and were not included in the analysis. A total of 101 sites were found to exist within the lower limit of the DEM and full pool elevation of the reservoir.

The minimum and maximum site elevations were interpolated from the perimeter of the archaeology site. The results were manually inspected to ensure that significant peaks or depressions do not exist within the site boundaries that would alter the minimum or maximum value of the site.

The drawdown zone of Arrow Lakes Reservoir was divided into elevation bands between 1410 and 1444 ft, corresponding to the elevation ranges used for the vegetation performance measure. The total number of archaeological sites within each band was tallied corresponding to its minimum and maximum elevation. Each elevation band was weighted based on the number of sites inventoried in each band to provide a relative importance modifier (Table 1).

**Table 1. Current Archaeological Site Inventory for Arrow Lakes Reservoir**

| | Elevation Range (ft) | | | |
|---|---|---|---|---|
| | 1410<band<1424 | 1424<band<1430 | 1430<band<1437 | 1437<band<1444 |
| Total sites within elevation band | 49 | 53 | 69 | 75 |
| Proportion of sites within band | 19.9% | 21.5% | 28.0% | 30.5% |
| Relative day weight | 0.65 | 0.71 | 0.92 | 1 |

(Note these numbers have been updated from those used in the NTSA process).

There are multiple ways to consider the potential for impact on impact on archaeological sites. Two different approaches are presented for consideration in evaluating alternatives.

**Performance Measure 1**

The first performance measure is based on concern over the potential for erosion of archaeological sites due to wave action. The number of days that the reservoir water level is within each elevation band over the year is weighted by the number of sites known in each band. The fewer the number of wave action erosion days, the better.

**Performance Measure 2**

The second approach emerged from discussions with First Nations. The method is based on the concept that keeping sites fully inundated can protect them from wind and wave erosion, as well as human disturbances. The number of days that the reservoir water level is at least 1 metre above each elevation band over the year is weighted by the number of sites known in each band. The greater the number of inundation days, the better. A 1-m buffer was applied to each elevation band to account for depth of erosion due to wave action.

## Calculation

For each alternative:

1. Assemble the simulated results for Arrow Lakes Reservoir elevations over 60 years (1940-2000; Figure 1).
2. Parameter (1): Count the number of days over the year that the reservoir is within each elevation band for each of the 60 years.
   Weight each day by the relative day weights listed in the Table 1 above, and sum across the four range bands.
3. Parameter (2): Count the number of days over the year that the reservoir is 1 metre above each elevation band and thus fully inundating each elevation band for each of the 60 years.
   Weight each day by the relative day weights listed in the Table 1 above, and sum across the four range bands.
4. Summarize all statistics (Figures 2 and 3).

## Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1928-1999).
- Assumes that the relative importance of any given recorded site is equal.
- Assumes that the relative survey effort across elevation zones is equal.

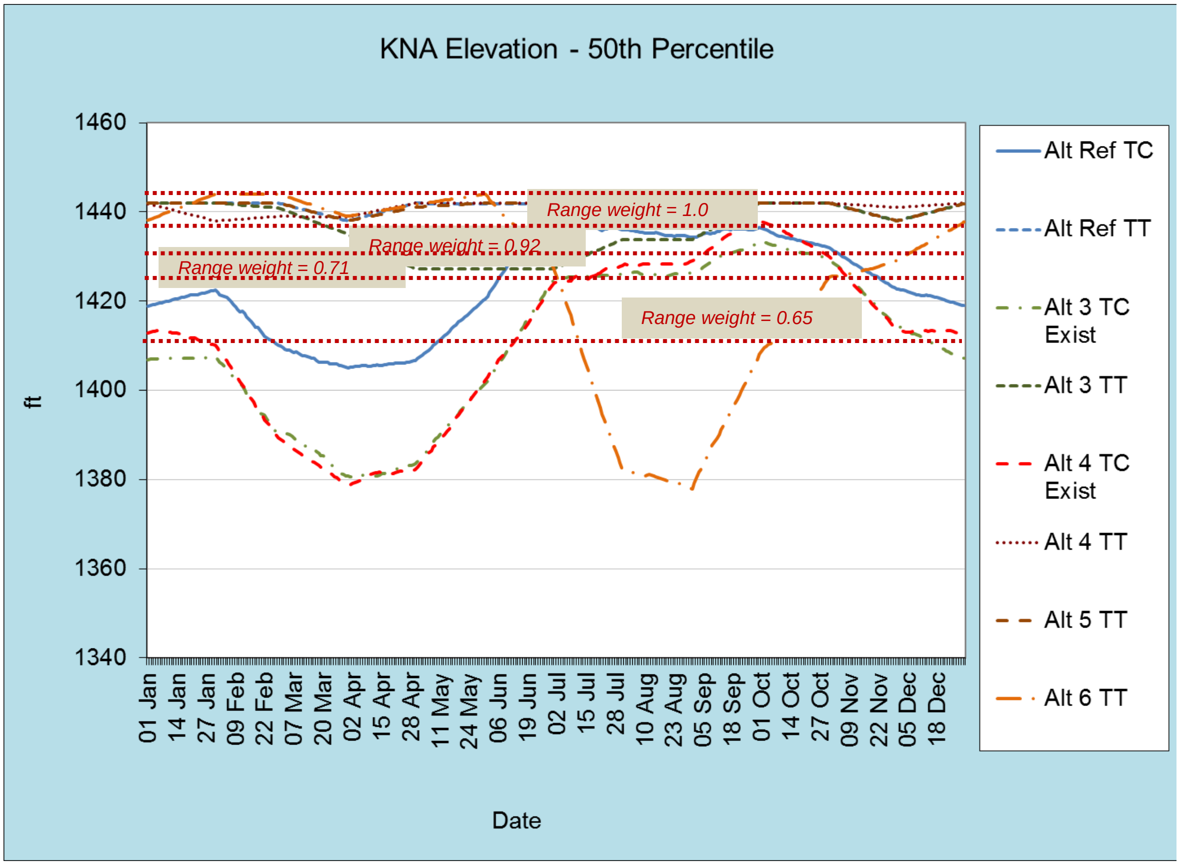
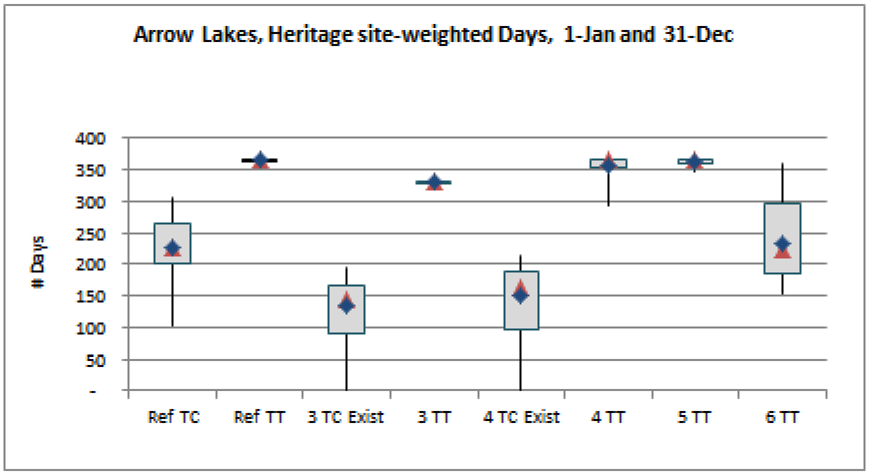



**Figure 1. Simulated Arrow Lakes Reservoir Elevations. Median over 60 years showing the weighted elevation bands for protection of identified heritage and cultural sites.**

## Results

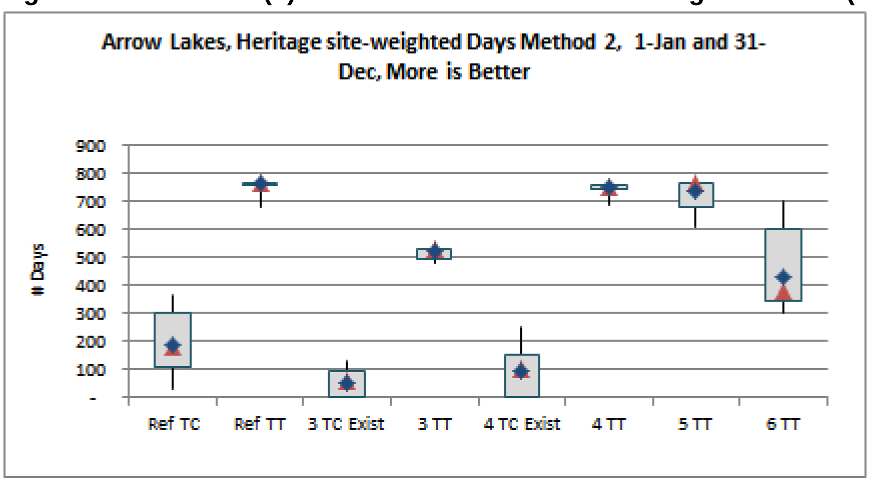
**Figure 2. Parameter (1): Erosion – Culture & Heritage – Results (High is bad)**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 305 | 365 | 195 | 333 | 213 | 365 | 365 | 360 | Max |
| 266 | 365 | 166 | 332 | 188 | 365 | 365 | 295 | 90th |
| 225 | 365 | 144 | 332 | 163 | 365 | 365 | 223 | Med |
| 227 | 365 | 135 | 332 | 151 | 357 | 363 | 233 | Mean |
| 200 | 365 | 91 | 332 | 96 | 352 | 361 | 185 | 10th |
| 104 | 365 | 1 | 331 | - | 292 | 346 | 154 | Min |

In the TT scenarios, the elevation is more often in the 1437<x<1444 band, which has the most sites and thus the most erosion disturbance.

**Figure 3. Parameter (2): Inundation – Culture & Heritage –Results (High is good)**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 365 | 772 | 131 | 533 | 255 | 768 | 772 | 700 | Max |
| 303 | 768 | 96 | 530 | 154 | 759 | 767 | 604 | 90th |
| 180 | 768 | 59 | 530 | 100 | 749 | 763 | 380 | Med |
| 190 | 763 | 56 | 524 | 95 | 750 | 735 | 430 | Mean |
| 109 | 758 | 1 | 497 | - | 747 | 678 | 342 | 10th |
| 29 | 680 | - | 481 | - | 689 | 610 | 302 | Min |

In the TT scenarios, the elevation is more often at least 1m above most of the sites, and therefore more sites are fully inundated and protected.

# PERFORMANCE MEASURE INFORMATION SHEET #18

## ARROW LAKES RESERVOIR: DUST

| Objective / Location | Performance Measure | Units | Description |
|---|---|---|---|
| Dust Control/ Arrow Reservoir | Dust potential days | # days elevation is below 1410 ft between 1 March and 30 April | Sum of # days per year that the reservoir water level is below 1410 ft when dust generation potential is highest in the lower elevations. |

## Description

During the Columbia WUP process, there was an explicit decision by the Consultative Committee to not consider areas below 1424 ft in Arrow Lakes Reservoir for evaluating the performance of the operating alternatives in providing benefits to vegetation or setting guiding principles for the WUP Revegetation Program. This decision was driven largely by the assumption that that these lower elevations would be addressed by BC Hydro's Dust Control Program.

Since 1987, BC Hydro has seeded significant portions of the Revelstoke Reach (Revelstoke to Shelter Bay) with fall rye for erosion control and dust abatement. The purpose of the program was to control the generation of air borne dust during low reservoir elevations prior to spring freshet and reservoir filling. Historically, dust storms have been of primary concern during spring prior to reservoir refilling and in low elevation areas where natural vegetation communities have not become established. The optimal range for planting fall rye was therefore based on the reservoir inflows forecasts and rate of refill for a given year.

On average, about 2500 acres were treated with fall rye seed each year (Boehringer 2010). This was modified annually based on projected water levels, shifts in dust source locations, and the encroachment/establishment of native vegetation on previously seeded areas. Due to concerns about the risk of straw matt formations in the reservoir (Moody 2003), application of fall rye seed was timed to limit its growth and maturity by direct inundation. Annual fall rye distributions in the drawdown zone were therefore highly dependent on the dates of seeding and subsequent water elevations.

The dust control program continued annually until 2008, after which time fall rye treatment was suspended and photo monitoring of dust activity was implemented at selected locations in the drawdown zone (Boehringer 2010). In lieu of treatments, the 2009 and 2010 programs focused on data collection and monitoring activities to increase the understanding of current conditions of remaining dust sources in Revelstoke Reach. This was driven by a number of assumptions around the current state of dust sources within the drawdown zone. Specifically, it was believed that planting of fall rye was no longer required at a number of historical treatment areas due to native plant encroachment and establishment into lower elevations. Further, planting for dust control would only be required at a reduced intensity because much of the vegetation in dust control treatment areas now regenerates naturally, leaving smaller areas to be seeded in each subsequent year.

Based on a historical analysis of the dust control program (Boehringer 2010), it has been recommended that additional field data be collected to assess future treatment needs. There are limited empirical data on vegetation communities that exist at the lower elevations targeted by the dust control program and factors beyond timing and extent of inundation that may be influencing the establishment of perennial and or annual vegetation at these lower limits.

## Performance Measure

For the NTS analysis, a performance measure was developed to examine the relative impacts of the four scenarios on dust generation potential in Arrow Lakes Reservoir. The metric tracks the number of days over the year that the reservoir elevation is below 1410 ft during the period when dust potential is highest (March 1 to April 30).[1]

## Calculations

1. Assemble the simulated results for Arrow Reservoir elevations over 60 years (1928-1999; Figure 1).
2. Count the number of days over the year that the reservoir is below 1410 ft between 1 March and 30 April for each of the 60 years.
3. Summarize all statistics (Figure 2).

[1] An elevation threshold of 1424 ft (434 m) was initially used in the analysis to correspond with the upper limit of the dust control program. However, this was found to be insensitive to the NTS scenarios and was masking differences at lower elevations.

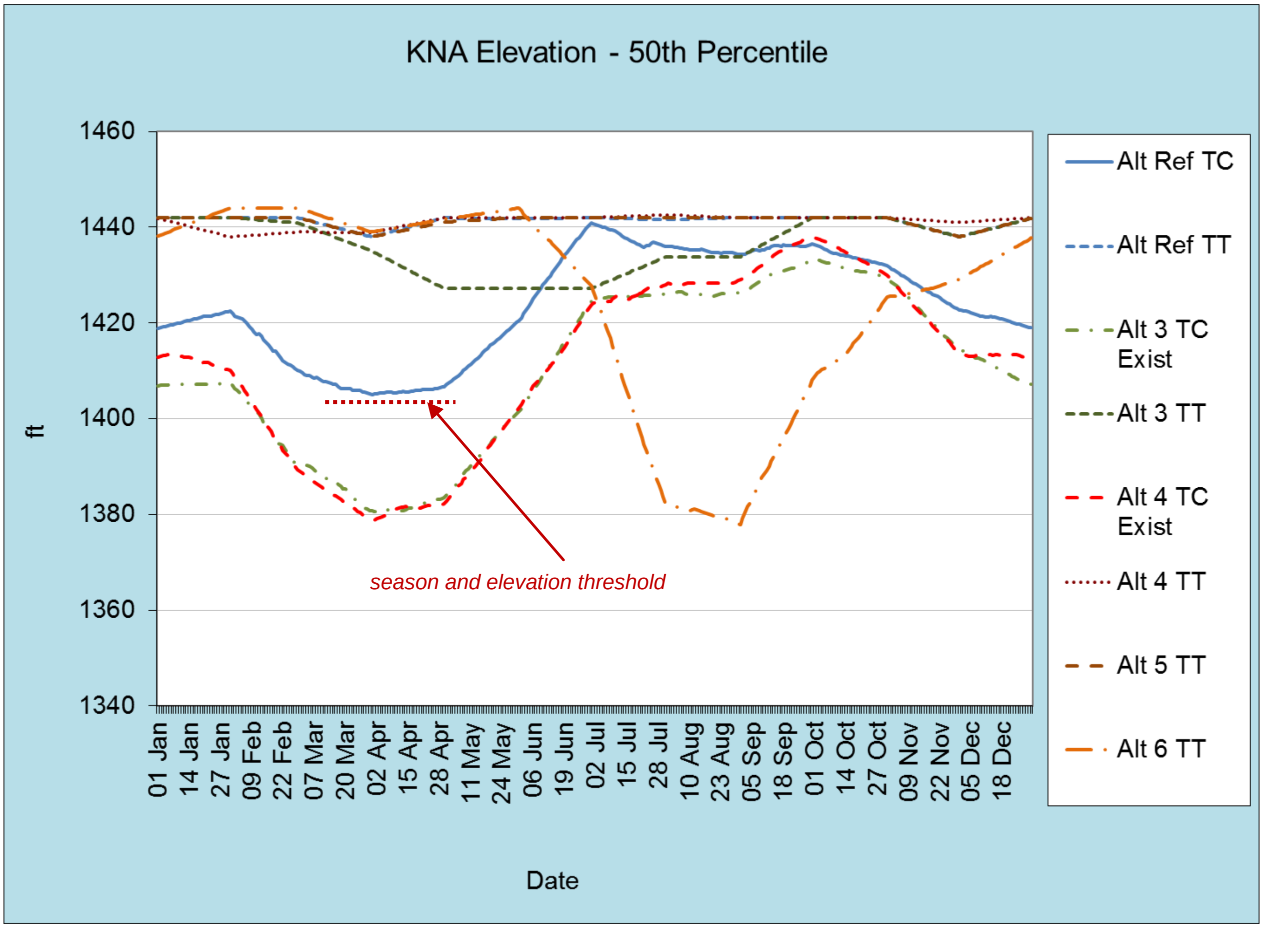



**Figure 1. HYSIM Simulated Mid Columbia River (Arrow Lakes) elevations. Median over 60 years showing the elevation threshold for dust control.**

## Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows.

## Results

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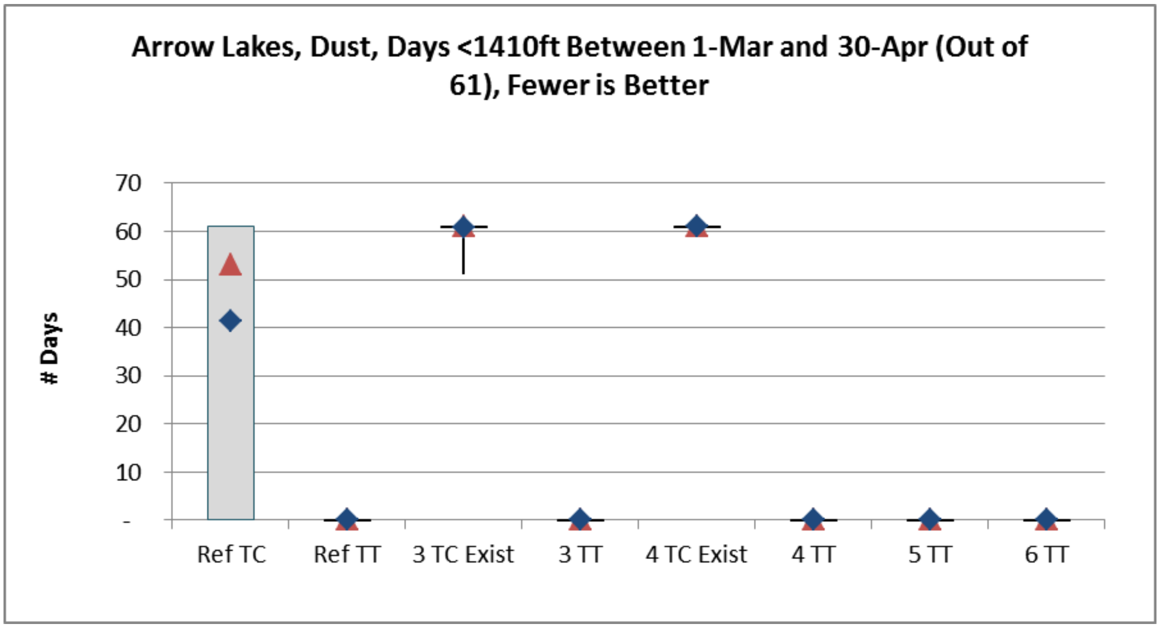
**Figure 2. Dust Control – HYSIM Results**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 61 | - | 61 | - | 61 | - | - | - | Max |
| 61 | - | 61 | - | 61 | - | - | - | 90th |
| 53 | - | 61 | - | 61 | - | - | - | Med |
| 41 | - | 61 | - | 61 | - | - | - | Mean |
| - | - | 61 | - | 61 | - | - | - | 10th |
| - | - | 51 | - | 61 | - | - | - | Min |

## References

Boehringer, E. 2010. Upper Arrow Lakes Reservoir (Revelstoke Reach) Dust Control Report 2010. Summary and Assessment of Treatment Data1987 to 2008. Prepared for BC Hydro, Environment and Social Issues, Castlegar. 30 pp.

Den Biesen, D. 2008. Arrow reservoir dust control program: 2007 Summary Report. Internal BC Hydro document. 25 pp. + plus appendices.

Moody, A. 2003. Assessment of Floating Plant Debris in Arrow Reservoir. Unpublished report prepared by Aim Ecological Consultants Ltd. for BC Hydro. 12 pp.

# PERFORMANCE MEASURE INFORMATION SHEET #20

## TRIBUTARY ACCESS FOR ARROW LAKES RESERVOIR: FISH

| Objective / Location | Performance Measure | Units | Description |
|---|---|---|---|
| Fish Soft Constraint/Arrow Reservoir | Tributary Access | # days above defined elevation thresholds between 25 August and 15 November:<br>*Original threshold = 1424 ft*<br>*Updated threshold = 1430 ft* | Sum of # days over the kokanee and bull trout spawning periods that the reservoir water level is above defined thresholds. |

## Description

During the Columbia WUP process, concern was expressed that seasonal changes in the elevation in Arrow Lakes Reservoir have the potential to negatively affect the ability of key fish populations (namely kokanee, bull trout and rainbow trout) to access critical spawning habitats in the Arrow Lakes tributaries. Reduced success in upstream passage can result from a variety of effects associated with the topographic configuration of the tributary fan, including gradient, channel depth and velocity, morphology (braiding), and sub-surface conveyance of tributary outflow.

While it was assumed that the effects of low spring reservoir elevation on spawning rainbow trout are, in part, mitigated by increased stream flow during tributary freshet, low reservoir levels during the fall spawning period for kokanee and bull trout was considered an issue by the WUP Consultative Committee. BC Hydro conducted several tributary access assessments in Arrow Lakes Reservoir in the fall (Bayes and Olmsted 1997, CCRIFC 2006, BC Hydro 1998, 2004-2006, and Wilson 1999). Although there were no reports of significant access issues related to low reservoir conditions, low flow access issues were observed in a small number of tributaries to the Lower Arrow.

As part of developing soft constraints for Arrow Reservoir operations, the Committee recommended an elevation target of 1424 ft over the period August 25 - November 15 to minimize potential impacts on fall spawners. This was thought to be the critical elevation below which some tributaries could become inaccessible over the kokanee and bull trout spawning periods.

The Committee acknowledged that further study would be required to resolve whether current operation of Arrow Lakes Reservoir is negatively affecting tributary access. A 5-year monitoring study (2008-2012) is currently underway to assess whether operation of the Arrow Lakes Reservoir is limiting upstream migration of spawners into tributary streams, whether there is a reservoir elevation threshold below which spawning access is affected, and to what extent stream flows mitigate low reservoir water levels in the spring. Preliminary findings from the first year (2009) of field study suggest that rainbow trout may not experience the same limitations as kokanee, as adfluvial trout spawning migrations coincide with spring freshet and periods of increased tributary discharges (Ecoscape 2010). However, operation of the reservoir can block or reduce upstream passage of kokanee during their fall spawning migration. Of the passage barriers identified in tributary streams, all of these were attributed to some combination of channel braiding, rock/debris barriers and low stream flows. In some tributaries, access was still a problem even when reservoir water levels were 4.5 ft above the elevation threshold set for the

Arrow soft constraint (1424 ft). Braided channels within many of the tributaries are highly dynamic and unstable, causing individual barriers to possibly migrate upstream/downstream as a result of bedload movement. Further surveys will be required to identify reservoir elevation thresholds above which channel stability is increased and elevational position where low flow barriers exist.

Based on the 2009 study results, seven tributaries were found to have barriers as a result of low stream flows, braided channels and or aggradation. The elevations of these obstructions ranged from 1418 ft to 1438 ft, with most occurring at or below 1430 ft. A second threshold for the Performance Measure was therefore included to report out on the number of days that Arrow Lakes Reservoir is above 1430 ft during the kokanee and bull trout spawning periods.

## Calculations

For each scenario:

1. Assemble the simulated results for Arrow Reservoir elevations over 60 years (1929-1999; Figure 1).
2. Count the number of days over the kokanee spawning period that the reservoir is at or above 1430 ft in each of the years.
3. Summarize all statistics (Figure 2 and Figure 3).

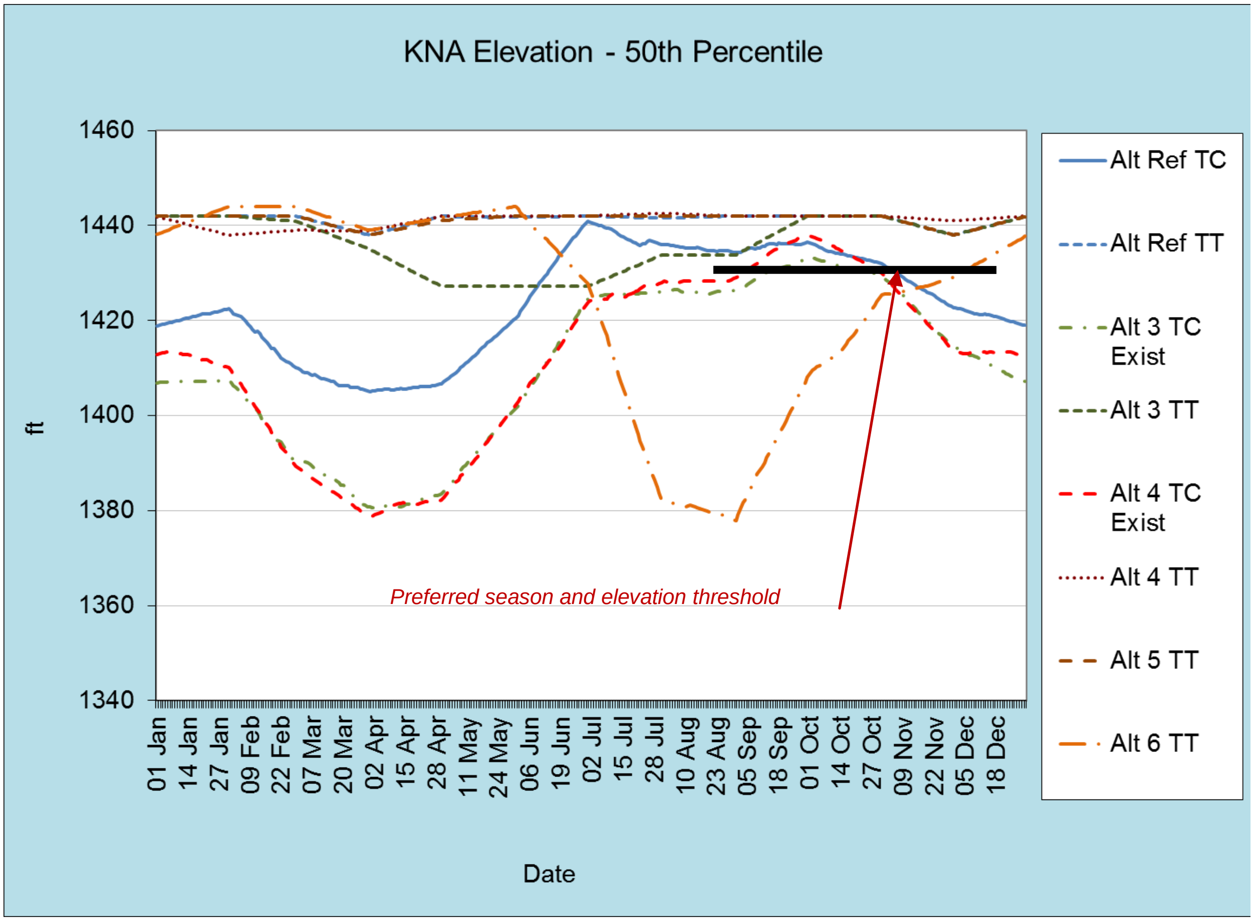
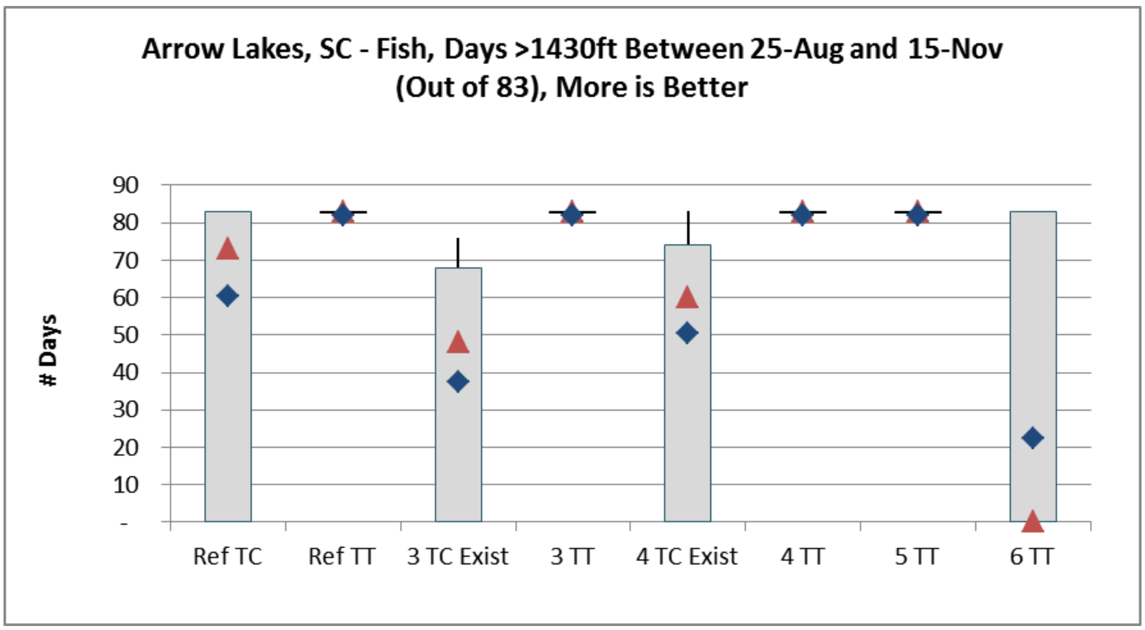



**Figure 1. Lakes Reservoir Elevations, showing the elevation target for tributary access.**

## Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1929-1999).
- Spawning windows do not vary from year to year either naturally or as a function of reservoir elevations and inflows.
- Uncertainty about critical reservoir elevation that limits access to important spawning tributaries.
- Factors other than reservoir elevation do not limit access of fish to tributary spawning habitats.

## Results




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 83 | 83 | 76 | 83 | 83 | 83 | 83 | 83 | Max |
| 83 | 83 | 68 | 83 | 74 | 83 | 83 | 83 | 90th |
| 73 | 83 | 48 | 83 | 60 | 83 | 83 | - | Med |
| 60 | 82 | 37 | 82 | 50 | 82 | 82 | 22 | Mean |
| - | 83 | - | 83 | - | 83 | 83 | - | 10th |
| - | 83 | - | 83 | - | 83 | 83 | - | Min |

**Figure 2. Fish Tributary Access: days > 1430 ft**

## References

Bayes, M. M., and W. R. Olmsted. 1997. A fisheries assessment of selected Arrow Lakes Tributaries. Prepared for Columbia Generation Area, Castlegar, BC.

BC Hydro. 1998. Unpublished BC Hydro Data – September-October Upper Arrow assessments.

BC Hydro. 2001. Unpublished BC Hydro Data – overview assessment of low flow issues on Arrow Lakes Reservoir

BC Hydro. 2003. dbFish: Annotated database of fisheries life histories for BC Hydro regulated watersheds. Prepared for Generation Operations, Burnaby, BC.

BC Hydro. 2006. Unpublished BC Hydro Data (2004-2006) – August assessments of Arrow Lakes Reservoir

Bray, K. and P. Mylechreest. 2007. Investigations into migratory movements, mortality, and age at maturity of Upper Arrow Reservoir bull trout (Salvelinus confluentus) Through Radio Telemetry. FWCP Draft Report.Canadian Columbia River Inter-Tribal Fisheries Commission (CCRIFC), 2006. kokanee use of Arrow Lakes Reservoir drawdown zone. Prepared for Columbia Generation Area, Castlegar, BC.

Ecoscape. 2010. Year 2 (2009) Fish Migration Passage Monitoring Summary Report. Arrow Lakes tributary fish migration access assessment and monitoring program. 23 pp + maps

Wilson, K. 1999. Cursory Upper Arrow tributary assessment. Prepared for Upper Columbia Generation, Revelstoke, BC.

# PERFORMANCE MEASURE INFORMATION SHEET #26

## LOWER COLUMBIA RIVER: RECREATION

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Recreation/Lower Columbia River | Access Days | # access days by activity by region | Sum of # days river flows are within the preferred ranges for shore-based and water-based activities | 7 days |

## Description

Flows in the lower Columbia River are a function of both flows out of Arrow Reservoir past Hugh Keenleyside Dam (HLK) and the Kootenay system past Brilliant Dam (BRD). Large and sudden changes in river flow have been noted to have detrimental effects on recreational interests, such as boat navigation and stranding, and safe access to shorelines.

Recreation access and associated benefits are important in lower Columbia River. Local communities benefit from improvements to the quality and diversity of recreation and tourism experiences through a greater quality of life, as well as through local economic development benefits that result from increased usage. A number of key factors that affect recreational quality and use include:

- Diversity and abundance of fish and wildlife, since many recreational activities are focused on enjoyment of these natural resources
- Ability to safely access the water or shorelines for water-based and shore-based activities
- Visual quality of viewscapes

During the Columbia WUP process, concern was expressed about daily flow fluctuations in the lower Columbia River, where flows can change dramatically from day to day or week to week. Due to the influence of the Kootenay River system and lack of control over flow changes (due to the constraints of the Columbia River Treaty), a modelling approach to capture these interests was not developed during the Columbia WUP process. It was agreed that boat access and shoreline access would capture most of the recreational interests in the lower Columbia River. For boat access, the Recreation Technical Subcommittee identified preferred flows over the recreation season that would provide "good opportunity" for a broad range of interests, including access via boat ramps, usability of boat ramps and quality of boating within that range of river flows. The boat access measure was not tied directly to physical structures (i.e., boat ramps). The shoreline access measure was defined around a range of flows that constituted "good opportunity" for shore-based activities, with activities decreasing in frequency when the flow is above or below this range.

## Performance Measures

The preferred range of river flows were developed based on critical water levels for viewshed quality, shoreline use, boat access and swimming, and mixed recreational use in the City of Trail (RL&L 2001, G. DeRosa pers. comm.[1]) The following table summarizes the flow levels highlighted in the RL&L report for the lower Columbia River.

[1] Trail Councillor Gord DeRosa has stated the City of Trail's preference for elevations are in the range of 404.9 and 408.1 metres for a variety of recreational and non-recreational (e.g., ambulance access) uses. In terms of flows,

**Preferred Flow Ranges for Lower Columbia River**

| Activity | Lower (cfs) | Upper (cfs) |
|---|---|---|
| Swimming | 78 035 | 99 327 |
| Sightseeing | 14 195 | 102 823 |
| Shore-based angling | 60 309 | 99 327 |
| Motor boating | 70 902 | 156 035 |
| Non-motorized boating | 70 902 | 102 823 |
| Boat-based angling[2] | 40 000 | 60 000 |

Based on these preferred flow ranges, a PM was developed for "boat access" to cover use of all boats on the river (motorized and non-motorized), including boat-based angling which occurs primarily during the June-August period. The PM definition for "shore-based access" overlaps with shore-based angling, and suggests that flows below the lower cut-off for swimming (78305 cfs) are adequate.

The primary seasons of water- and shore-based activities were modified from that used during the WUP based on feedback from local user groups. The seasons are defined as follows:

**PM Definitions**

| Area | Measure | Dates | Critical Flow Zone |
|---|---|---|---|
| Lower Columbia River | Boat Access Days | 1 May to 15 Sep | # days HLK + BRD flow between 40 000 and 102 823 cfs |
| | Shoreline Access Days | 1 May to 30 Oct | # days HLK + BRD flow between 60 309 and 99 327 cfs |

## Calculations

For each scenario:

1. Assemble the simulated results for total Arrow discharges (HLK) and average daily Brilliant (BRD) flows over (1948-1997; Figure 1).
2. Interpolate month-end HYSIM data to daily flows.
3. Count the number of days over the defined recreation season for each year that the total river flows from HLK and BRD fall within the preferred ranges for boat access and shoreline access.
4. Summarize all statistics (Figures 2 and 3).

### Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1948-1997).
- Assumes that there is minimal recreational use outside the defined recreation season.

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these correspond to 1841cms (65 000cfs) to 3540cms (125 000cfs), according to information in the Indian Eddy Marina Development Project Review (BC Hydro).

[2] Preferred flow ranges for boat-based angling (i.e., pool formation) have been added for the NTS analysis based on input from members of the West Kootenay Fly Fishers Association.

- Assumes that the preferred season and elevations are accurate and are capturing the essence of access issues for boating and shoreline use.

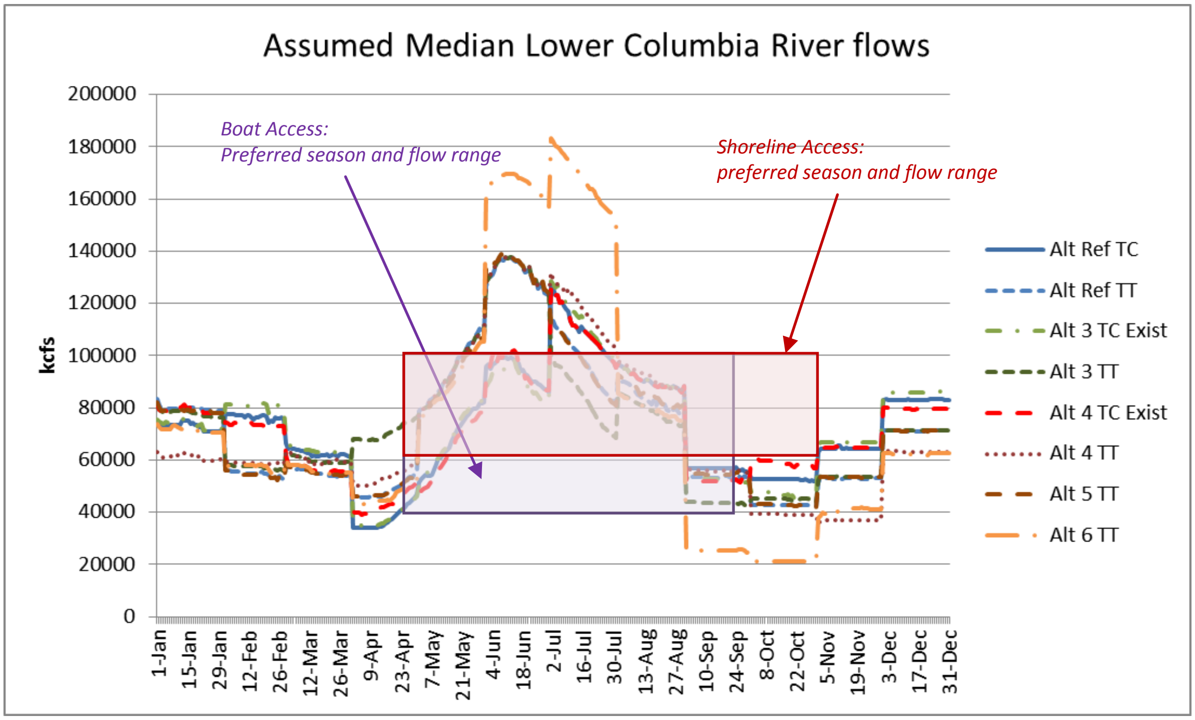
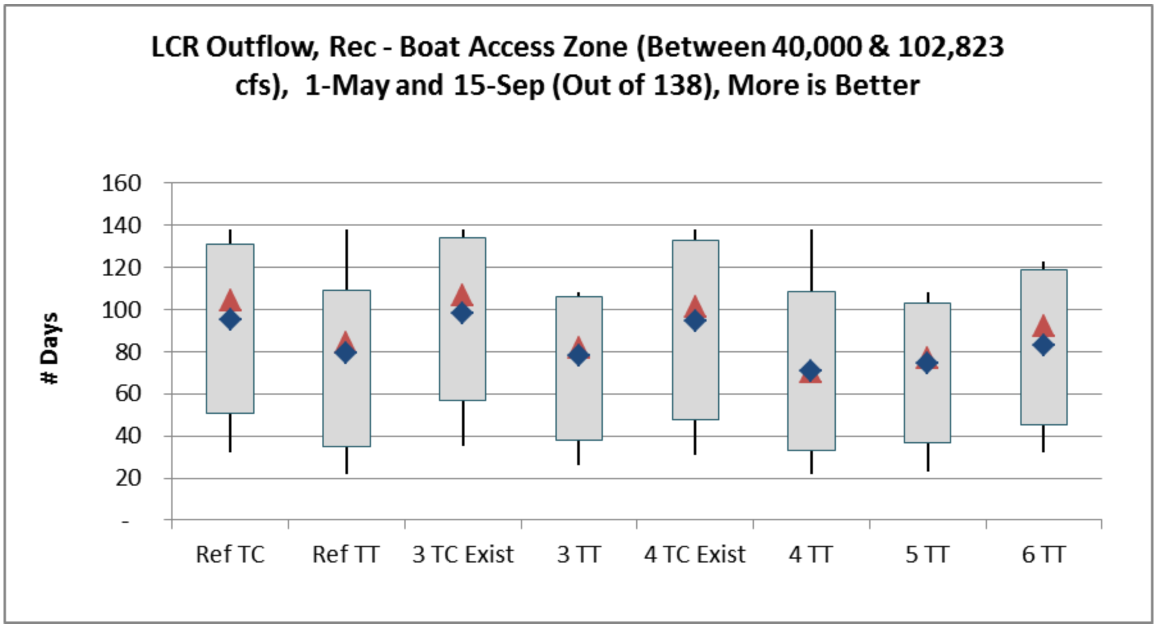



**Figure 1. Simulated Lower Columbia River Flows**

## Results

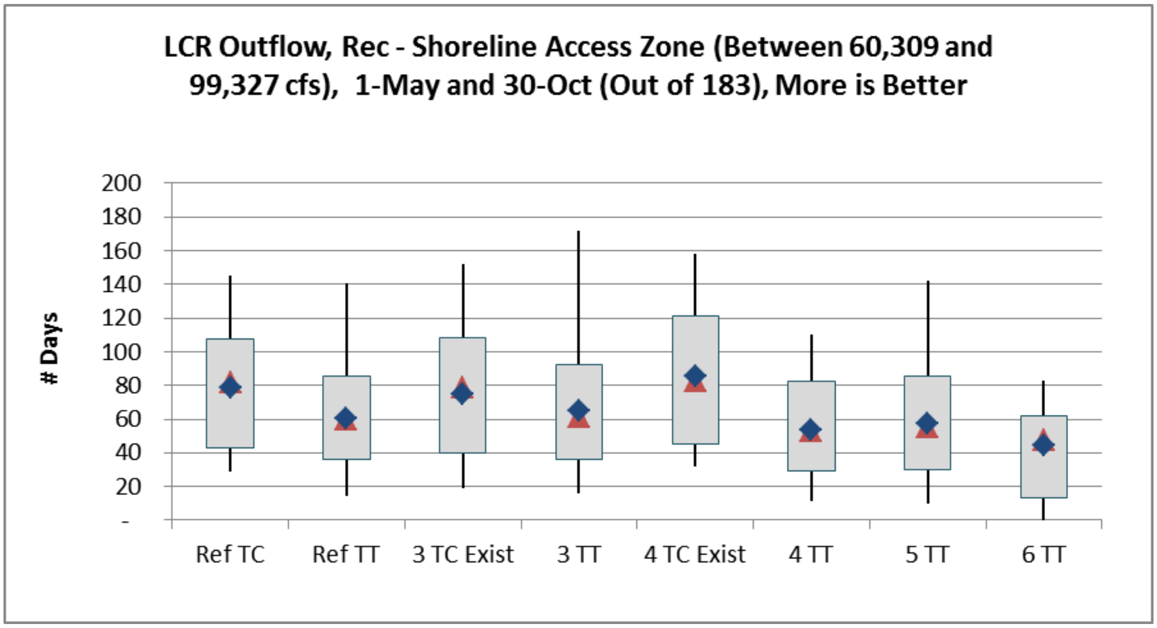
**Figure 2. Boat Access Days**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 138 | 138 | 138 | 108 | 138 | 138 | 108 | 123 | Max |
| 131 | 109 | 134 | 106 | 133 | 109 | 103 | 119 | 90th |
| 104 | 84 | 107 | 82 | 101 | 71 | 77 | 92 | Med |
| 95 | 79 | 98 | 78 | 94 | 71 | 75 | 83 | Mean |
| 51 | 35 | 57 | 38 | 48 | 33 | 37 | 45 | 10th |
| 32 | 22 | 35 | 26 | 31 | 22 | 23 | 32 | Min |

**NOTE:** Values for alternative 5TT have not been adjusted to account for the pulse flow associated with this alternative

**Figure 3. Shoreline Access Days –**




| Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT | |
|---|---|---|---|---|---|---|---|---|
| 145 | 141 | 152 | 172 | 158 | 110 | 142 | 83 | Max |
| 108 | 85 | 108 | 92 | 121 | 82 | 85 | 62 | 90th |
| 82 | 60 | 79 | 61 | 83 | 53 | 55 | 48 | Med |
| 79 | 61 | 75 | 65 | 86 | 54 | 57 | 45 | Mean |
| 43 | 36 | 40 | 36 | 45 | 29 | 30 | 13 | 10th |
| 29 | 14 | 19 | 16 | 32 | 11 | 10 | - | Min |

**NOTE:** Values for alternative 5TT have not been adjusted to account for the pulse flow associated with this alternative

## References

RL&L Environmental Services Ltd. 2001. Water Use Plans – Environmental information review and data gap analysis. Volumes 1 & 2. Prepared for BC Hydro, Burnaby by RL&L Environmental Services in association with Robertson Environmental Services Ltd., Pandion Ecological Research Ltd., Bruce Haggerstone Landscape Architect, Pomeroy & Neil Consulting Ltd. and DVH Consulting. RL&L Report No. 858V1-F.

# PERFORMANCE MEASURE INFORMATION SHEET #27

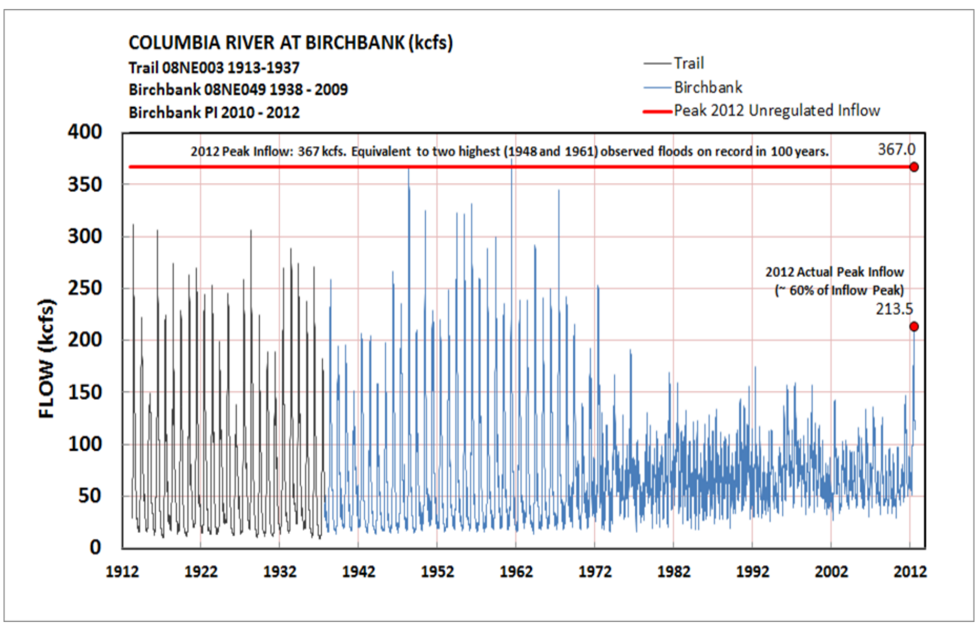
## LOWER COLUMBIA RIVER: FLOOD CONTROL

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Flood Control/ Lower Columbia River | Frequency of Flood Flows | # of day per year flows exceed 165 000 cfs | Frequency with which flows potentially flood property in Genelle | N/A |
| | Infrastructure | # of day per year flows exceed 72,000 cfs | Frequency with which flows potential flood the Trail sewer service road | N/A |
| | | # of day per year flows exceed 177,499 cfs | Frequency with which river flows limit use of the Indian Eddy ramp | N/A |

## Description

Under normal operations, Arrow Lakes Reservoir discharge (spill and generation at ALH) is not expected to exceed 100 kcfs or cause river flows at Birchbank (Kootenay River plus total ARR discharge) to exceed 180 kcfs. Onset of minor flooding issues is known to occur along the lower Columbia River at discharges exceeding 180 kcfs.The current Columbia River Treaty Flood Control Operating Plan sets onset of significant flooding impacts at 225 m3/s and major damages at > 280 kcfs.

Castlegar and Trail have experienced significant flood events in the past (e.g. 1948 and 1961). However, since construction of the Columbia River hydroelectric facilities, the likelihood of lesser events has been substantially reduced from historic levels. Since project construction, there have been three inflow years comparable to 1948 without any significant downstream impacts on Castlegar or Trail.



During the recent high flow event (July 2012), a peak flow of 215 kcfs was measured at the Birchbank gauge – this was the highest recorded river flow during the 40-year period (since 1973) with all upstream reservoirs operational. The actual peak flow event in 2012 is not inconsistent with the results of a theoretical flood-frequency study done by BC Hydro in the early 1980's, in which the 30-year regulated peak flow for this site was estimated at 225 kcfs. Associated with the 2012 flow events, the following incremental issues were observed in the downstream floodplain at flows greater than 180 kcfs:

1. > 180 kcfs: Access restrictions to Zuckerberg Island causeway (Castlegar), Millennium Park (Castlegar) and Trail ( Gyro Park)
2. > 180 kcfs Increasing issues with Trail sewage processing (Aging Infrastructure, not original design capability).
3. > 185 kcfs: Whispering Pines (Genelle) access to ancillary road restricted
4. > 190 kcfs: Erosion issues Robinson sewage lagoon (Castlegar), river front backyards flooded (Twin Rivers: Castlegar).
5. > 195 kcfs: Access to Zuckerberg Island (Castlegar) cut off.
6. > 215 Incremental risk to Trail river retaining walls when dewatering from 215 kcfs to 165 kcfs

During the Columbia River WUP, a flow threshold of 165 kcfs at Genelle was used as an initial benchmark for the onset of high flow impacts in the lower Columbia River. (This was based on observations taken during a relatively high flow event in 1992. At that time, the Whispering Pines septic field was impacted at 165 kcfs, whereas remediation work has been undertaken since then and this impact was not observed in 2012.)

For the NTSA analysis, two additional thresholds were also developed to consider the potential for flooding of infrastructure in the City of Trail as provided in the following table (provided by G. De Rosa, City Councillor Trail, pers. correspondence).

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**Critical Flow Thresholds for Trail Infrastructure**

| | Critical Elev. (ft) | Critical Flows (cfs) |
|---|---|---|
| Sewage treatment site | 1325 | 50,000 |
| Base of river wall | 1327 | 58,636 |
| **Sewer service road at Old Bridge Road** | **1330** | **72,000** |
| **River access/egress at Indian Eddy for emergency rescue** | **1344** | **177,499** |
| Loss of beach at Gyro Park | 1345 | 182,000 |
| Downtown basement flooding begins | 1349 | 223,000 |

Potential flooding impacts associated with the CRTR alternatives are also measured using the same flow levels as the NTSA (165 kcfs, 177 kcfs, and 72 kcfs), as estimated at the Birchbank gauge.

## Calculations

For each alternative:

1. Assemble the simulated results for total flow in the Lower Columbia River over 50 years including total discharges from Arrow Lakes combined with total Kootenay River flows from Brilliant Dam (Figure 1). For the CRTR process, Brilliant Dam discharges were assumed to be those associated with Kootenay system Alternative 1 (i.e. the modeled current operations).
2. Count the number of days per year that exceed the flow threshold.
3. Summarize all statistics (Figures 2-4).

## Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1948 – 1997).

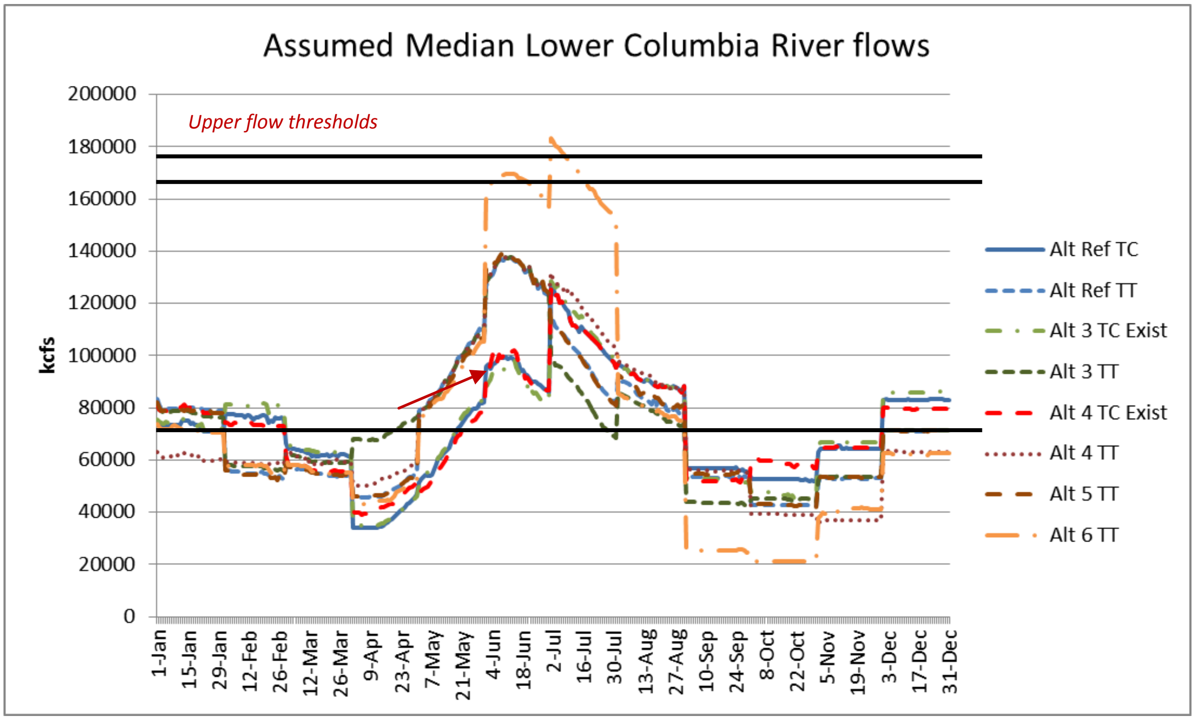
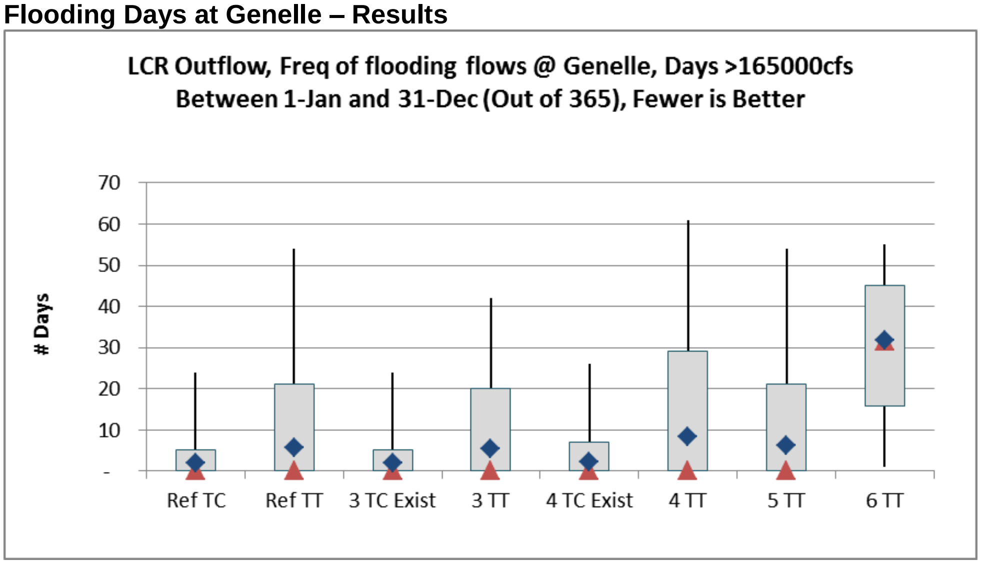



**Figure 1: Assumed median LCR flows with thresholds**

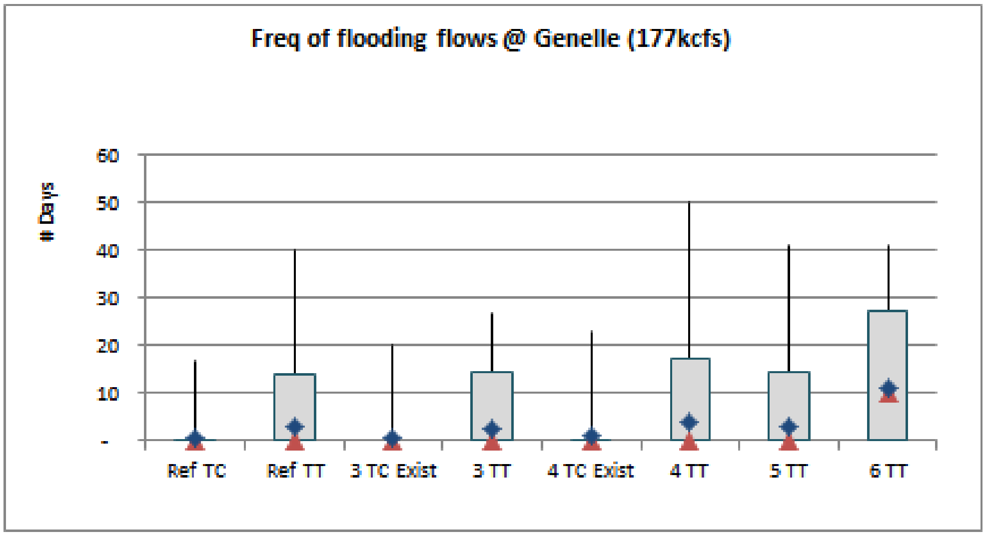
Note: The effects of the short pulse flow associated with Alternative 5TT have not been incorporated into this figure.

## Results

**Flooding Days at Genelle – Results**



| | Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT |
|---|---|---|---|---|---|---|---|---|
| Max | 24 | 54 | 24 | 42 | 26 | 61 | 54 | 55 |
| 90th | 5 | 21 | 5 | 20 | 7 | 29 | 21 | 45 |
| Med | - | - | - | - | - | - | - | 32 |
| Mean | 2 | 6 | 2 | 6 | 2 | 8 | 6 | 32 |
| 10th | - | - | - | - | - | - | - | 16 |
| Min | - | - | - | - | - | - | - | 1 |




| | Ref TC | Ref TT | 3TC Exist | 3 TT | 4 TC Exist | 4 TT | 5 TT | 6 TT |
|---|---|---|---|---|---|---|---|---|
| Max | 17 | 40 | 20 | 27 | 23 | 50 | 41 | 41 |
| 90th | 0 | 14 | - | 14 | 0 | 17 | 14 | 27 |
| Med | - | - | - | - | - | - | - | 10 |
| Mean | 1 | 3 | 1 | 3 | 1 | 4 | 3 | 11 |
| 10th | - | - | - | - | - | - | - | - |
| Min | - | - | - | - | - | - | - | - |

# PERFORMANCE MEASURE INFORMATION SHEET #30

# COLUMBIA SYSTEM POWER VALUE

| Objective / Location | Performance Measure | Units | Description | MSIC |
|---|---|---|---|---|
| Columbia River Generating Facilities | Incremental Cost | $M per year | Average annual loss in the value of electricity relative to Ref TC.<br><br>Lower is better | $ 0.5 M / yr |

## Description

The combined power generation facilities at Mica and Revelstoke facilities produce approximately 38 percent of BC Hydro's annual energy. Constraints on reservoir elevations and river flows may affect the value of power generated by these projects..

For the CRTR process, power value is assumed to comprise three factors:

**Change in Operating Benefits** After operations meet the stated constraints of each alternative, the model attempts to maximize for power value. The annual energy and value to the BC Hydro system are determined.

**Firm Energy Replacement Cost** If the constraints of an alternative were expected to have a significant impact on BC Hydro's firm energy then the loss of firm energy was approximated as replacement energy would be needed.

**Canadian Entitlement** This is the financial value associated with the Canadian Entitlement under the CRT. Under the Treaty Terminate scenario, there would be no Canadian Entitlement

In addition, the facilities also support a variety of ancillary services that could be affected by operational constraints. If a significant loss of service occurs in one part of the system, the service must be replaced or obtained elsewhere. The most important services include voltage control, supplemental reserves and dynamic scheduling. No performance measure was developed for ancillary services, as historic modelling results have suggested that it would not be affected by the scenarios considered.

## Calculations

. The value of the annual operational power benefit and the Canadian Entitlement is based on the BC Hydro electrical price forecast in 2024 (average market price of $38 MWh). The firm energy value is based on BC Hydro's reference price of $129/MWh, which is the replacement cost of clean energy built in BC.

## Key Assumptions and Uncertainties

- Various assumptions for the value of future energy have been made.

**Results**

Table 1 summarizes the values for the three components of Power Value for each alternative. These numbers are illustrated in Figure 1.

Note that three of the Treaty Terminate alternatives could result in a net increase in operational benefit relative to Ref TC due to the increased flexibility afforded by this scenario. However, in each case, the combined value of the other two components forces the net change to be negative relative to Ref TC.

**Table 1: Summary of Components of Power Value**

| ($m / yr) | **Ref TC** | **Ref TT** | **3 TC** | **3 TT** | **4 TC** | **4 TT** | **5 TT** | **6 TT** |
|---|---|---|---|---|---|---|---|---|
| Change in Operating Benefits(1) | 0 | 20 | -22 | 14 | -39 | -8 | 19 | -1 |
| Firm Energy Purchases (2) | 0 | | | | -142 | -142 | | |
| Canadian Entitlement (3) | 0 | -200 | | -200 | | -200 | -200 | -200 |
| **Net change from Ref TC** | **0** | **-180** | **-22** | **-186** | **-181** | **-350** | **-181** | **-201** |

(1) Operating benefit = value from model simulation);
(2) Alt 4 TT and TC have a loss of 1100 GWh of firm energy. Using a replacement cost of $129 (which is the reference price based on the last call) this is $142 million per year.
(3) Canadian Entitlement value based on 2024 average electricity price forecast plus a premium due to the high capacity value.

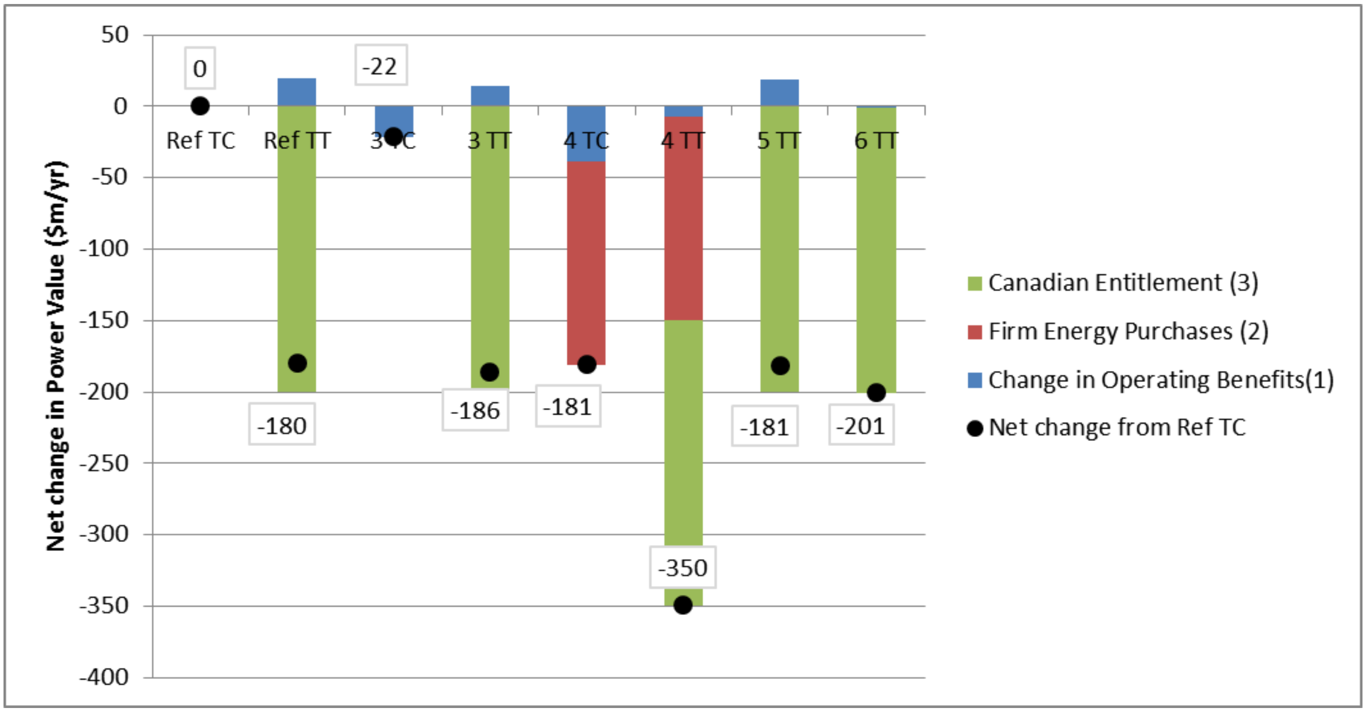



**Figure 1: Summary of Components of Power Value**