

APPENDIX C

DENDROGEOMORPHOLOGICAL ANALYSIS PROCEDURES

C.1. HEART CREEK DENDROGEOMORPHOLOGY

C.1.1. Introduction

Dendrochronology is an absolute dating method in which annually distinct tree rings are used to determine the age of a tree.

Dendrogeomorphology, a sub discipline of dendrochronology, focuses on geomorphological processes that influence tree growth. Depending on the ages of trees along the main stem channel of a creek, and the history of disturbing geomorphic events, dendrogeomorphology can extend the frequency record of debris flows well past the air photograph record and may close the time gap between air photograph interpretation (several decades) and radiocarbon dating (century to millennia). Unlike the other two methods, dendrogeomorphology can also be precise to the nearest year in dating growth disturbances, and in some cases, even the seasonal timing of growth disturbance can be deciphered (Stoffel and Bollschweiler, 2008).

Dendrogeomorphological methods have been applied specifically to debris flow which can influence regular tree growth in different ways (Alestalo, 1971; Stoffel and Bollschweiler, 2008).

- Trees may be damaged due to impact by large boulders or logs transported by a debris flow, producing scars or shearing the tree off above the stump in extreme cases (decapitation).
- Some trees species will produce tangential traumatic resin ducts (TRDs) when scarred or decapitated¹
- Tree growth may be reduced or increased in years following a debris-flow event due to changes in resource (water/nutrients) access.
- Growth pattern may also change when a tree is tilted and produces denser (and thus darker) reaction wood to regain vertical alignment.

Because trees produce a new layer of radial growth each year, these events can be accurately dated by studying the tree's growth ring series.

C.1.2. Method

157 trees were sampled between April 10 and May 8, 2014 from coniferous trees along Heart Creek. Three species were sampled: Engelmann spruce (*picea engelmannii*), white spruce (*picea glauca*) and Douglas fir (*pseudotsuga menziesii*).

Non-lethal wedges on scarred trees were extracted via electric chain saw or hand saw from trees that were undercut by erosion of the 2013 debris flow and had toppled into the channel.

¹ When a spruce or fir tree is wounded, the tree forms aligned rows of resin ducts, known as tangential TRDs. TRD formation is a defense mechanism that allows the tree to compartmentalize the damaged wood. By contrast, resin ducts in pine trees do not align after damage.

Full disks were extracted from trees that had previously been felled or had fallen. Two cores per tree were extracted from living trees using a 4 mm increment borer. Coring is a non-destructive sampling technique and is thus preferred to felling the tree. Permission to collect samples was granted by the Alberta Tourism, Parks and Recreation division, effective March 11, 2014 to December 31, 2014.

Retrieved samples were sanded to a high finish using 80, 120, 220, 320, 400 and 600 grit sand paper and scanned using a calibrated Epson scanner at 1600 dots per inch (dpi). The tree ring widths were measured using Regent Instruments' WinDENDRO 2012 software package (Regent Instruments Inc., 2012). WinDENDRO is a semi-automatic image analysis program, which identifies tree rings and measures the width of the yearly growth. The user inputs the outer ring year (normally 2013, unless the sample was extracted from a dead tree), and the program counts inwards from the bark along a user-defined path. The operator is also able to review and correct the ring assignments as necessary. WinDENDRO can be superior to manual dating techniques because it facilitates verification; when errors are found, measurement image files can be easily opened, adjusted and re-saved.

Once the samples have been measured, the ring-width variability among series was compared visually (list method) and statistically using the program COFECHA (Holmes, 1983). This process is known as "crossdating" and it is used to identify measurement errors. When using COFECHA, crossdating accuracy is interpreted based on the strength of Pearson's correlations (r) among tree-ring series ($p < 0.001$). For this project, samples were internally crossdated first, in which a sample is compared to other samples from the same tree. Once internal crossdating was complete, samples from across the fan were crossdated to form a master on-fan chronology. Crossdating of the master chronology allowed for further refinement and correction of the tree age and ring width measurements.

Based on the crossdating, samples were divided into four categories:

1. Samples that crossdate into the master chronology.
2. Samples that internally crossdate, but do not cross-date well with the master.
3. Samples that do not internally crossdate, but are accurately measured.
4. Samples that cannot be measured, due to poor quality or missing segments, or samples that were lost or broken during preparation.

Samples in the first three categories were used in the analysis; samples in the fourth category were discarded. It was recognized that dates for samples from the first category could be used with a high degree of confidence, whereas ring dates from the second and third categories may be imprecise by a few years. For Heart Creek, 51% of samples were in the first category, 24.5% were in the second category and 24.5% were in the third category. There were no samples lost or rejected for the Heart Creek analysis.

The first step in the analysis was to identify the event response features shown on each sample, for each year. The following response features were documented: tangential

traumatic resin ducts (TRDs); reaction wood; and impact scars. This process was known as feature identification.

The second step in the analysis was to identify the growth variations in each sample. Standard practice is to identify growth variations visually, either directly from the samples (Bollschweiler et. al., 2010) or using growth curves (Stoffel, 2010). However, confident and repeatable visual identification proved difficult for these samples, so a function called “pointer” from the dplR library in the free statistical software package R was used (R Project, 2014). When run on a single tree ring series, “pointer” determines the percent difference in ring width between time t and time $t-1$, and flags differences that are over or under a certain threshold. For the purposes of this project, it was determined that a 30% absolute growth variation between years corresponded to a visually observable growth variation in the core, so 30% was selected as a suitable threshold.

The third step involved combining the feature identification and growth variation identification results into a spreadsheet, on file at BGC. The spreadsheet was processed to produce a Global Mapper workspace with a number of map layers: one for each year of the dendrogeomorphological record on the Heart Creek fan (Blue Marble Geographics, 2014). In this workspace, each tree sample appeared as a coloured dot, with different colours corresponding to different tree reactions, or combinations of reactions. For example, a bright red dot indicated that tree had been scarred in the given year.

In conjunction with the historical air photos, these map layers were used to identify event years, and to delineate event extents. The following criteria were used to identify an event on the Heart Creek fan:

- At least one tree showing unambiguous scarring, and/or at least three trees showing TRDs or reaction wood.
- Presence of trees showing growth reduction with dates that match scarring or TRDs.

Once potential events were identified, the following principles guided the determination of an event year:

- A tolerance of ± 5 years was given to category 2 and 3 trees when matching reactions to an inferred event date (to account for possible errors due to lack of successful crossdating).
- Regional flooding events on the Bow River and local creeks were not used to identify event years, but were used to refine the timing of inferred events. If a debris-flood event was inferred within 2 years of a known flooding event, the date of the event was assigned to the date of the regional flooding event. This applied for category 1, 2 and 3 samples. Although there is a high degree of confidence in category 1 date assignments, it is possible, for example, that the particular core did not capture the first year of TRDs, or that reaction wood did not begin forming for a few years.

Once reliable debris flood areas have been delineated, their volumes were estimated empirically (see Section 6.0 in this report).

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