CONTROLS ON FLUVIAL GEOMORPHOLOGY IN THE CANADIAN ROCKY MOUNTAINS

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ABSTRACT

Kevin T. Quinlan: Controls on Fluvial Geomorphology in the Canadian Rocky Mountains
(Under the Direction of Tamlin M. Pavelsky)

The Canadian Rocky Mountains record a dynamic history of erosion. Presently, bedrock rivers interact with the lithology and structural architecture of a large fold-and-thrust belt. Because the alpine landscape has been modified by Pleistocene and Holocene glaciation, rivers are also influenced by relict glacial landscape features. Here, we use topographic analysis and rock erodibility data to test the impact of lithology and glacial influence on fluvial form and incision potential in the headwaters of the Athabasca River Watershed. For 30 streams, we identify spikes in normalized channel steepness (k_{sn}) where fluvial incision is focused. Results show that proximity to major lithologic contacts is not a predictor of knickzone location. Instead, bedrock channels are most perturbed from equilibrium where they flow over convexities at the intersection between hanging valleys and mainstem valley walls. These results suggest that glacial imprinting—mediated by variations in bedrock geology—controls Holocene erosion in this region.

ACKNOWLEDGEMENTS

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CHAPTER 1: CONTROLS ON FLUVIAL GEOMORPHOLOGY IN THE CANADIAN ROCKY MOUNTAINS

1. INTRODUCTION

Mountain topography is the result of tectonic deformation modified by erosion via glacio-fluvial processes. In unglaciated alpine environments, bedrock rivers record the impact of tectonic, climatic, and lithologic variations on mountain landscape development (Tinkler and Wohl, 1998; Whipple, 2004; Kirby and Whipple, 2012). The erosive capacity of detachment-limited streams controls the movement of materials through the geomorphic system and thus creates mountainous physiography (Seidl and Dietrich, 1992). Absent external perturbation, these stream profiles approach a smooth, concave-upward form in which gradient and discharge are adjusted to equilibrium (Ritter et al., 1995). When disrupted from equilibrium, streams may erode the underlying substrate until equilibrium is restored. As such, a fundamental relationship links a river's morphology to its potential for incision (Sklar and Dietrich, 1998; Whipple and Tucker, 1999). Analysis of fluvial geomorphology in mountain environments reveals regional patterns of erosion and therefore elucidates the modern history of landscape evolution (Burbank and Anderson, 2011).

In the modern Canadian Rocky Mountains, bedrock rivers are the dominant agents of Holocene landscape modification. These streams flow over complex and variable fold-and-thrust belt geology in a landscape recently modified by alpine glaciation (9-10 ka), with ice now limited to only extreme elevations (Gadd, 2009). In these types of post-orogenic, paraglacial environments, alpine channel form and incision patterns are primarily controlled by variations in bedrock strength and glacial preconditioning of the landscape (Ballantyne, 2002; Hobley, 2010; Whitbread, 2012). However, the relative importance of these factors in control of Holocene fluvial geomorphology is not fully understood. Recent studies of bedrock channel morphology have primarily addressed actively uplifting orogenic systems with comparably homogenous bedrock geology and little or no recent glacial activity (e.g. Kirby et al., 2003; Whipple, 2004; Safran et al., 2005; Wobus et al., 2006; Kirby and Whipple, 2012). Fewer studies have performed channel analysis in tectonically passive mountain belts with a history of glaciation (e.g. Bishop and Goldrick, 2010; Egholm et al., 2013). The manner in which fluvial form (and therefore topography) evolves in mountain belts following both orogenesis and glaciation remains an area of open inquiry.

This study uses topographic analysis and field-based proxies for bedrock strength to evaluate the principal controls on fluvial geomorphology within the Canadian Rocky Mountains. We focus on the montane portion of the Athabasca River watershed in Alberta (Figure 1). The Athabasca and its tributaries drain a landscape that is representative of the lithology, structure, and glacial imprinting throughout the orogen. By quantifying channel form and rock erodibility, we seek to understand the relative influence of bedrock geology and glacial imprinting on patterns of fluvial morphology and erosion in the Canadian Rocky Mountains.

2. BEDROCK RIVER MORPHOLOGY

Bedrock rivers are high-gradient channels developed in reaches of exposed bedrock where the underlying substrate exerts a primary influence on fluvial process (after Tinkler and Wohl, 1998). It is not uncommon for these streams to experience periodic cover of alluvial gravels, though this cover is largely mobilized during high-flow events (Seidl and Dietrich

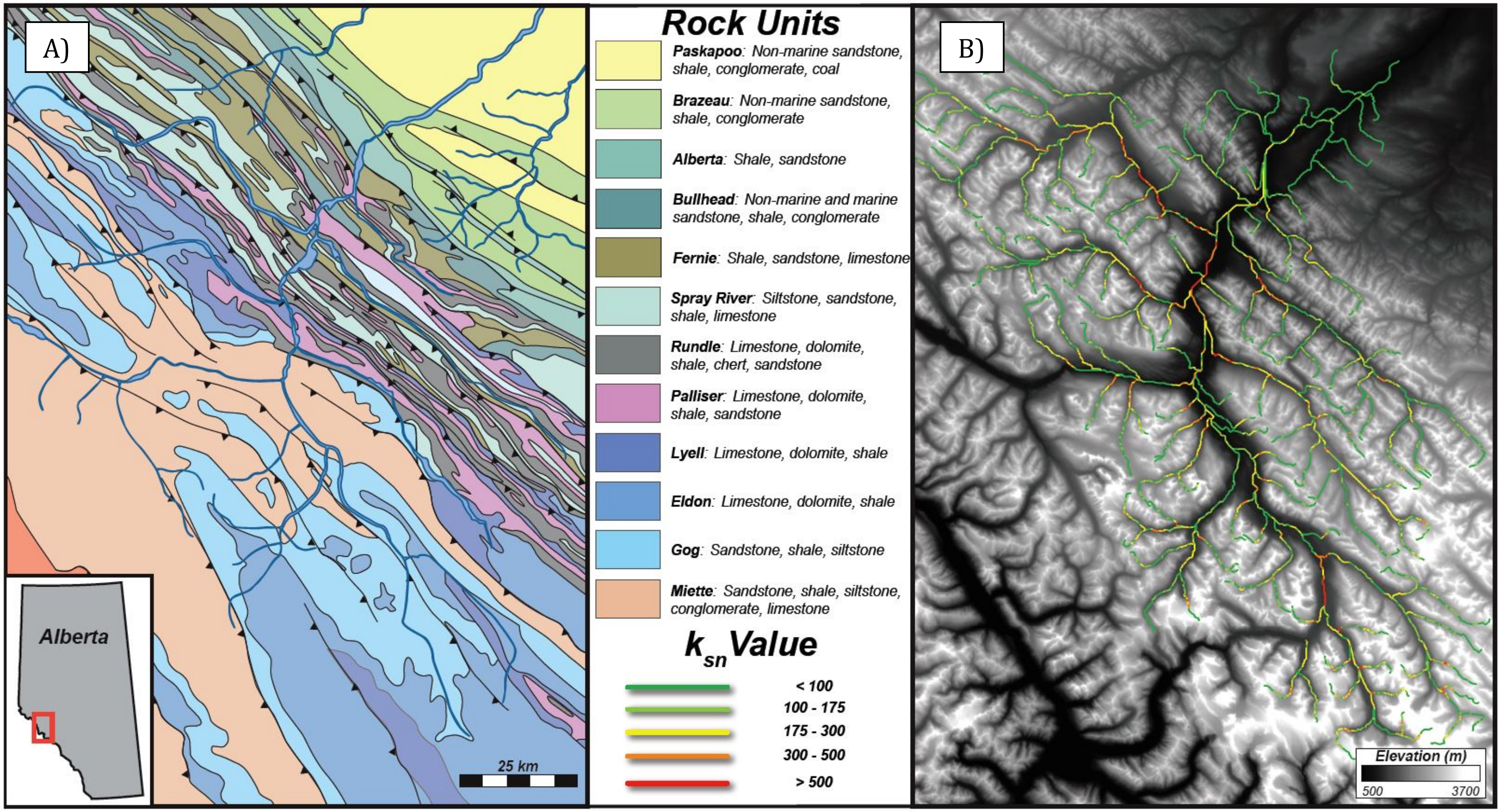

Figure 1. Geology, topography, and steepness patterns in the Athabasca basin headwaters. (A) Bedrock geology is represented at the 1:1,000,000 scale, highlighting the major structural and stratigraphic relationships between major formations in the vicinity of Jasper National Park. Modified from Price et al., 1973. (B) Stream network for major drainages in the montane portion of the Athabasca River watershed. Colors represent per-pixel normalized steepness value (k_{sn}).

1993). In such fluvial environments, the primary agents of bedrock erosion are abrasion and quarrying, the former producing more constant (though less efficient) erosion and the latter producing more infrequent, high magnitude erosive events (Hancock et al., 1998). Importantly, the detachment-limited nature of bedrock channels causes these reaches to experience unidirectional morphological change. Whereas alluvial rivers "repair" erosive changes in the streambed with mobile sediment (Leopold et al., 1964), erosion in bedrock rivers creates permanent alterations to the channel form. Consequently, bedrock river processes control patterns and rates of topographic evolution in mountainous regions (Kirby and Whipple, 2012).

The relationship between channel slope (S) and upstream drainage area (A) in natural rivers is commonly expressed by the power law relationship:

$$S = k_s A^{-\theta} \quad (1)$$

in which k_s is steepness index and θ is concavity index (Flint, 1974). Repeated study has shown that the relationship in Equation 1 is robust for a great variety of rivers worldwide (e.g. Howard and Kerby, 1983; Whipple and Tucker, 1999, Ouimet et al., 2009; Karlstrom et al., 2012; and many others). Physically, this equation describes the equilibrium form of a river: at low discharges (approximated here as low contributing drainage area) streams must be steep to move water and sediment; at greater discharges, sediment can be transported at shallower gradients. Thus, when a stream is in equilibrium, gradient and contributing drainage area scale predictably according to Equation 1 and values of k_{sn} do not vary greatly along the length of the river.

Streams in disequilibrium do not exhibit a predictable relationship between slope and drainage area (Kirby and Whipple, 2012). In such reaches, local gradient may be much greater than expected and consequently the value of normalized channel steepness index (k_{sn}) must locally increase to balance Equation 1. Spikes in k_{sn} identify areas where the river deviates substantially from equilibrium form. We classify these reaches as knickzones (Haviv et al., 2010). Along a channel's profile, knickzones correspond with reaches where the river is responding to external forcing.

In mountain environments, common external forcings on channel form include tectonic perturbations, changes in bedrock lithology, inherited landscape features, and variations in climate (Stock and Montgomery, 1999; Kirby and Whipple, 2001; Duval et al., 2004; Cyr et al., 2008). In the Canadian Rock Mountains, where tectonic activity is quiescent, we attribute the greatest possibility for perturbation to a combination of variable bedrock lithology and landforms inherited from recent glaciation. Calculating the normalized channel steepness index (k_{sn}) for all points along a stream channel identifies both the magnitude and spatial extent of perturbation within the fluvial system. Thus, Equation 1 provides insight into the source of external forcing driving disequilibrium of fluvial geomorphology in the Canadian Rocky Mountains.

3. GEOLOGIC SETTING

3.1 Geology

The Canadian Rocky Mountains are an alpine landscape topographically characterized by steep, jagged, high-relief peaks (Cruden and Hu, 1999; Price, 2001). This Northwest-striking mountain belt is a thin-skinned fold and thrust system formed during a complex period of terrane accretion dated to the Cretaceous and early Paleocene (Bally et al., 1966; Monger et al., 1982; Price, 1994; Evenchick et al., 2007; Simony and Carr, 2011). Unlike the predominately crystalline rock of the Southern Rockies, the Canadian Rockies are largely composed of marine siliciclastic and carbonate sedimentary rock (Price and Mountjoy, 1970) (Figure 1A). Locally this rock has been metamorphosed at low grade (greenschist facies) to slate and quartzite and rarely to higher grade schist (Charlesworth, 1967; Gadd, 2009). In the study area, rock ranges in age from the metasediments of the Precambrian Miette Group (850 – 542 Ma) to the siliciclastic Paleocene Paskapoo Formation (62 – 58 Ma) (Price et al., 1973). Though igneous intrusives cross-cut the Canadian Rockies cover sequence, no substantial outcrops exist within the study area (Gadd, 2009).

Physiographically, the study area can be divided into three major provinces: the Main Ranges, Front Ranges, and Foothills (Fermor and Moffat, 1992; Osborn et al., 2006). Within the study area, the high peaks of the Main and Front Ranges abruptly transition to the muted topography of the Foothills east of the orogen-bounding thrust fault. In the southwest of the study area, the mountains of the Main Ranges are composed of Cambrian and Precambrian metasediments including the Neoproterozoic Miette Group, Lower Cambrian Gog Group, Middle Cambrian Eldon Formation, and Upper Cambrian Lyell Formation. The mountains of the Front Ranges are composed of the comparably younger siliciclastics and carbonates of the Devonian Palliser Formation, Carboniferous/Permian Rundle Group, Triassic Spray River Group, Jurassic Fernie Formation, Lower Cretaceous Bullhead Group, and Upper Cretaceous Alberta Group. In the Northeast of the study area, the Foothills consist of the youngest rock in the region: the Upper Cretaceous Brazeau Formation and Paleocene Paskapoo Formation (Price et al., 1973).

3.2 Geomorphology

Structural, stratigraphic, and geochronological data suggest that the Canadian Rocky Mountains were at a uniformly high elevation (i.e. an orogenic plateau) immediately following uplift ~55Ma (e.g. Price and Fermor, 1985; Kalkreuth and McMechan, 1996; Sears, 2001). The modern topography bears no resemblance to this ancient landscape. It has therefore been proposed that differential erosion via surface processes has created the modern mountain physiography (Osborn et al., 2006). This hypothesis contends that bedrock resistance to erosion is the principal factor governing long-term (10^6 year scale) landscape development in the study area. The complex history of topographic evolution highlights the importance of glacial and fluvial erosion in the geomorphic history of the Canadian Rocky Mountains.

The modern drainage pattern of the upper Athabasca River watershed is strongly controlled by geologic structure (Figure 1B). The Athabasca River is the major trunk stream in the study region and cuts across structure, flowing northeast from the Rockies and across the adjacent plains to its outlet in Lake Athabasca. In the Main and Front Ranges, NW/SE oriented thrust sheets create a trellis drainage system with major streams parallel to the strike direction of the orogen. Smaller first- and second-order detachment-limited tributaries flow perpendicular to these strike-parallel channels. Consequently, these low-order bedrock rivers flow directly across major lithologic contacts in the fold-and-thrust structure. In the Foothills, where structural control is less prevalent and bedrock is more homogeneous, drainage shifts from trellis to dendritic in form.

The Canadian Rocky Mountains represent an alpine environment transitioning from dominantly glacial to primarily fluvial erosion processes. As recently as 9ka during the Wisconsinan glacial episode, the region was glaciated as ice from the local alpine glaciers merged with the adjacent Cordilleran and Laurentian continental ice sheets (Yorath and Gadd, 1995). Only the most extreme elevations in the mountain belt (~ >3300m) would have stood above the ice cover as nunataks (Gadd, 2009). Though the Wisconsinan glaciation was in retreat by ~14ka, ice may have occupied alpine valleys well into the early Holocene. In the last 9ka, the study area has been in a period of glacial retreat with permanent ice limited to peak elevations

(Osborn and Luckman, 1988). Movement of materials through the modern environment is controlled mainly by the fluvial network of the basin. In particular, incision is focused at the scale of first-order bedrock rivers. In these streams, the geomorphic imprint of glaciation remains immediately evident. Following deglaciation, rivers reoccupied the valley networks and transported substantial fluxes of paraglacially derived sediment while reestablishing equilibrium fluvial form.

The valleys modified by glacial erosion are characteristically U-shaped and commonly feature hanging valleys where tributary alpine glaciers once met trunk valley glaciers (MacGregor et al., 2000; Amundson and Iverson, 2006). Glacial erosion is proportional to ice mass; consequently, smaller tributary glaciers did not remove as much material from valleys as larger trunk glaciers (Anderson et al., 2006). As such, the tributary streams that occupy these valleys after deglaciation do not meet trunk streams at grade (Braun et al., 1999).

The result of the geomorphic mismatch between tributary and trunk glaciers is a longitudinal profile convexity commonly known as a hanging valley. Hanging valleys are characteristic features of high alpine zones in the Athabasca River Watershed. Because they constitute a preferential flow pathway, hanging valleys in the study area now frequently contain streams (Amundson and Iverson, 2006). These zones of convexity are a substantial perturbation from equilibrium form and thus create large knickzones upstream of the fluvial tributary-trunk confluence (Valla et al., 2010). Bedrock rivers incise gorges into these hanging valley knickzones as they move materials to reestablish an equilibrium profile (Crosby and Whipple, 2006). Thus, hanging valleys may be a principal source of glacial imprinting on fluvial form in the Canadian Rockies.

4. METHODS

4.1 Field Data

To quantify rock erodibility and observe channel morphologies for bedrock rivers in the Canadian Rocky Mountains, we collected field measurements in the vicinity of Jasper National Park in Summer 2013. Rock erodibility was quantified in the field via intact rock strength (as measured by Type N Schmidt Hammer) and by fracture density (Duvall et al., 2004; Goudie, 2006; Duhnforth et al., 2010). The relationship between Schmidt Hammer rebound value, fracture density, and bedrock resistance to erosion has been well demonstrated: greater rebound value and lower fracture density correspond to lower potential for erosion, and vice versa (Selby, 1980; Moon and Selby, 1983; Cargill and Shakoor, 1990).

Using 1:500,000 scale geologic maps, we selected 54 bedrock outcrops for erodibility analysis by proxy of intact rock strength and fracture density (Figure 2). Outcrops proximal to bedrock streams were preferred. The selected outcrops encompass all major rock formations in the regional stratigraphic section and range in age from Neoproterozoic through Cenozoic. Where appropriate, we subdivided formations with substantial intraformational facies changes. Specifically, the interbedded Jurassic Fernie sandstone and shale were sampled separately, as were the Miette gritstone and slate.

For each sample site, we conducted 40 rebound compressions on exposed rock surfaces at a minimum distance of 6 inches from the nearest fracture plane. Consistent with previous studies, we rejected measurements that pulverized the rock, elicited a hollow noise upon impact, or produced a rebound value below 11 (Kirby et al. 2003; Snyder et al., 2003; Duvall et al., 2004; Allen et al., 2013).

Fractures facilitate erosion by increasing rock surface area exposed to physical and chemical weathering processes (Hancock et al., 1998). Therefore, we measured fracture spacing at all bedrock outcrops to complement the Schmidt Hammer measurements and more thoroughly quantify bedrock erodibility. We used scan lines perpendicular to dominant bedrock fracture orientation to measure fracture spacing across the length of the outcrop. To assess variability in the density of bedrock fractures across the study area, we used an analysis of variance (ANOVA) test to compare the mean values of fracture density for all major lithologic units.

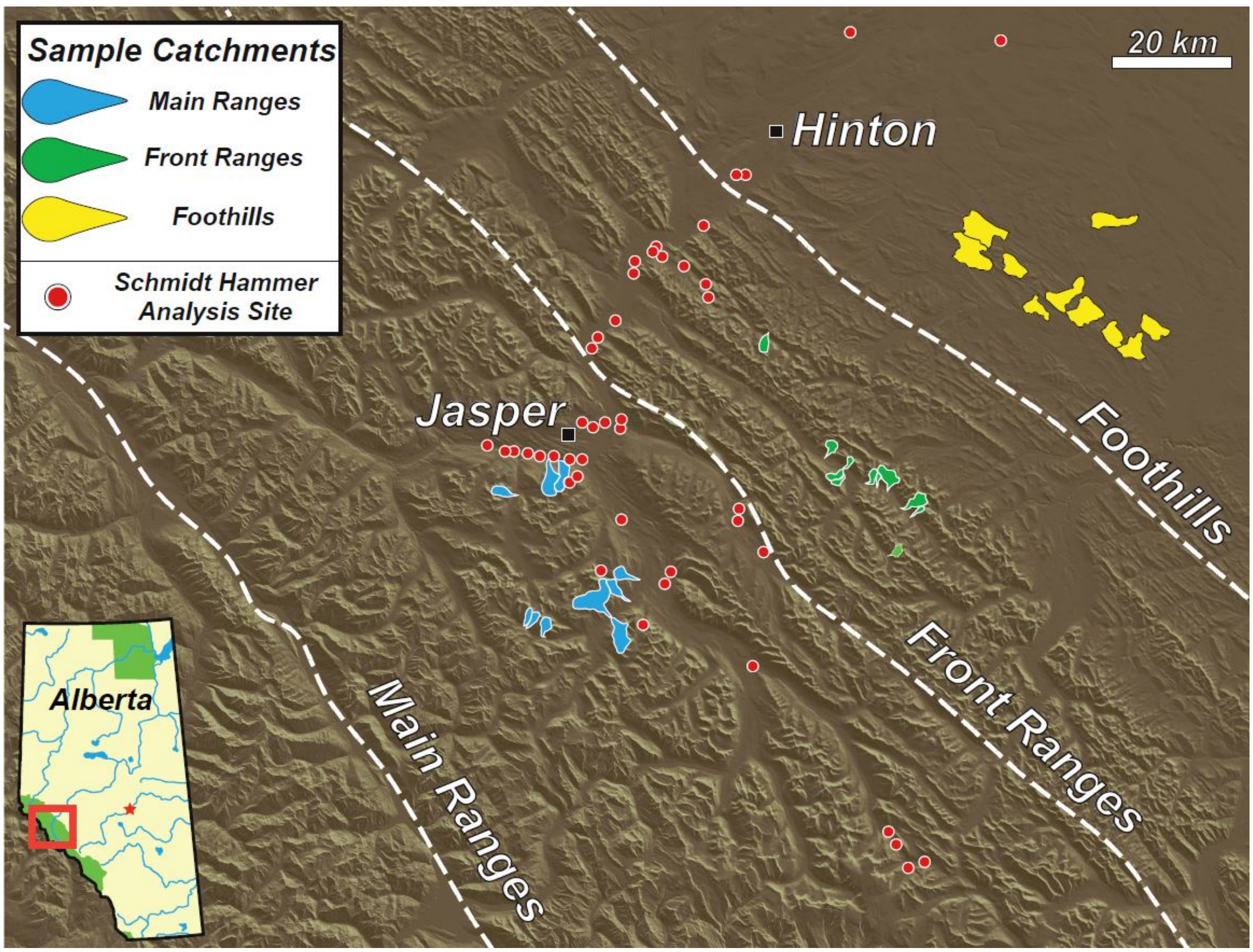

Figure 2. Map of measurement sites. Schmidt Hammer test locations are represented by red circles. Catchments isolated for quantitative stream morphology analysis are shown in blue (Main Ranges), green (Front Ranges), and yellow (Foothills).

4.2 DEM Analysis

To better understand the extent to which bedrock geology and glacial preconditioning control fluvial form and incision patterns, we analyzed their spatial correlation with normalized steepness index (k_{sn}) values along stream profiles in the montane portion of the Athabasca River watershed. Many previous studies have demonstrated a positive, monotonic relationship between normalized steepness index (k_{sn}) and rate of channel incision (e.g. Safran et al., 2005; Harkins et al., 2007; DiBiase et al., 2010; Cyr et al., 2010; Miller et al., 2012). We analyzed channel morphology using the 0.75 arc-second (~18m resolution) Canadian Digital Elevation Data (CDED) Digital Elevation Model provided by the Canadian GeoBase project (www.geobase.ca). The source data in the DEM is derived from the Canadian National Topographic Data Base (NTDB). We selected this data product for its high spatial resolution and relative lack of noise.

We interpreted variations in k_{sn} along channel profiles to be a proxy for incision potential. To locate areas of high incision potential (i.e. knickzones), we calculated per-pixel k_{sn} values for all streams above a minimum 2.5 km^2 contributing drainage area in the study region using ArcGIS and Matlab methods written for the GeomorphTools plugin (following Snyder et al., 2000; Kirby et al., 2003). To facilitate regional stream comparison and to avoid autocorrelation of variables, we assigned a fixed regional concavity index (θ_{ref}) of 0.45 to determine a normalized steepness index (k_{sn} in units of $m^{0.9}$) for points along all streams in the regional drainage network. The selection of this value for concavity index is consistent with previous studies (Safran et al., 2005; Wobus et al., 2006).

We compared the distribution of k_{sn} values proximal to major lithologic contacts with intra-formational (or "background") k_{sn} values to test for signals of incision potential associated with changing lithology. This analysis addressed the extent to which localized changes in bedrock geology across the study area exerted any control on river form and incision patterns. Using a georeferenced 1:1,000,000 scale geologic map (Price et al., 1973), we identified all locations where streams in the study area crossed lithologic contacts between rocks with statistically different mean rebound values (95% confidence). We extracted k_{sn} values for all pixels within a 500m radius of these contacts. The selection of a 500m radius reduced the likelihood of erroneously misrepresenting the location of lithologic contacts (i.e. if the mapped location and the true location of the contact differ, or if the knickzone associated with the contact had migrated along the channel profile). For comparison, we then extracted k_{sn} for all stream pixels in the entire drainage network, excluding those within the 500m radius of each contact.

To isolate the effects of bedrock geology and glacial preconditioning, we selected 10 sub-basins within each of the three physiographic zones (a total of 30 catchments) for quantitative channel steepness analysis (Figure 2). For all 30 basins, we calculated k_{sn} values at 18 m intervals along the major bedrock streams draining the catchments. Selected streams are first-order bedrock channels between 4 and 10 km in length that traverse lithologic contacts (some also cross major geologic structures). The selected catchments are representative of the bedrock geology and regional topography exhibited in the three major physiographic provinces.

5. RESULTS

5.1 Rock Erodibility

Schmidt Hammer rebound data for the 54 measured bedrock outcrops show that rock strength and stratigraphic age are positively correlated (Figure 3A). The softest rock in the study area comprises the Cretaceous and Paleocene cover sequence exposed at the Foothills. The Paleocene Paskapoo and Upper Cretaceous Brazeau formations are very friable in outcrop and yielded many discarded compression values (rebound < 11). By contrast, the hardest rock in the region is the Lower Cambrian Gog Group, a notable ridge-forming unit comprised of very well indurated quartzose sandstone. Schmidt Hammer analysis yielded no significant differences of intact rock strength between siliciclastic and carbonate rock. However, all major shale/slate formations yielded uniformly low rebound values.

There are substantial regional variations in erodibility between Main Range, Front Range, and Foothills bedrock (Figure 3B). Using a Mann-Whitney-Wilcoxon non-parametric test, we found that the rock of the Main Ranges (mean rebound = 54±7) is harder than that of the Front Ranges (mean rebound = 45±9) at a statistically significant level (p-value < 2.2×10^{-16}), just as the rock of the Front Ranges is significantly harder than that of the Foothills (mean rebound = 28±6). This trend is consistent with the development of regional physiography: the high, steep peaks of the Main and Front ranges are held up by old, hard rock while the comparably subdued topography of the Foothills is underlain by weak rock unable to support steep slopes (Osborn et al., 2006). A notable exception to this relationship is the slate member of the upper Proterozoic Miette Group (mean rebound = 21±6). This extremely weak bedrock underlies much of the Miette River valley including the Jasper Townsite. However, its inability to form ridges means that this bedrock is not a major contributor to the development of mountainous topography in the Main Ranges. For this particular reason, we considered only the ridge-forming gritstone and sandstone members of the Miette Group for our analysis.

ANOVA test demonstrated that variance in fracture density across outcrops of the same rock type is as great as or greater than the variance between the means of different rock formations. As such, there is no statistical reason to believe that fracture density varies significantly between different major rock formations and is not likely to be a major contributor toward regional contrasts in erodibility potential. We therefore considered only the Schmidt Hammer rebound data in our assessment of rock erodibility.

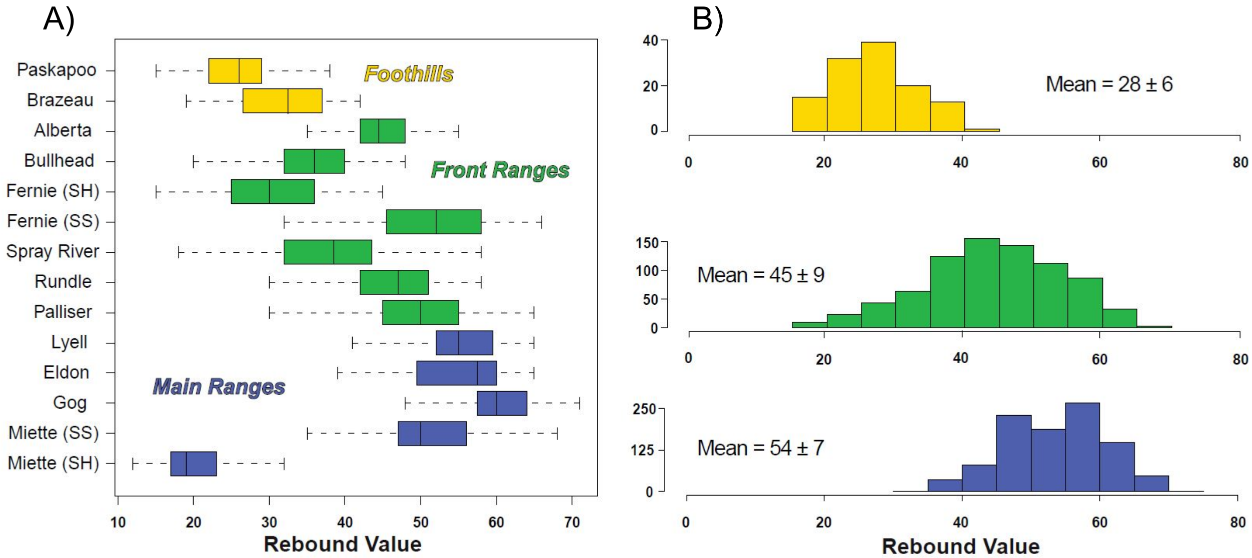

Figure 3. Schmidt Hammer rebound data. (A) Boxplot of rebound values for all major geologic formations in the study area, arranged in stratigraphic order from youngest at top to oldest at bottom. Increasing rebound value corresponds to decreasing potential for erodibility. (B) Histograms for rock rebound values, grouped by physiographic province, excluding Miette shale.

5.2 Channel Morphology

Comparison of channel steepness values within and outside of a 500m radius of contacts yielded no statistical evidence that streams flowing over contacts are substantially steeper than they are elsewhere in the drainage network (Figure 4). For stream pixels proximal to lithologic contacts, mean k_{sn} was 105±65m$^{0.9}$. The mean k_{sn} for all stream pixels in the study area (excluding those within 500m of contacts) was a similar value of 108±101m$^{0.9}$. In addition to a slightly lower mean steepness value, the percentage of pixels proximal to contacts with a very high channel steepness value (k_{sn} > 200m$^{0.9}$), which are indicative of knickzones, is 7.3% while the percentage of pixels distal from contacts exceeding k_{sn} values of 200m$^{0.9}$ is 13.4%. Given these findings, there is no evidence that knickzones are disproportionately abundant in the vicinity of lithologic contacts.

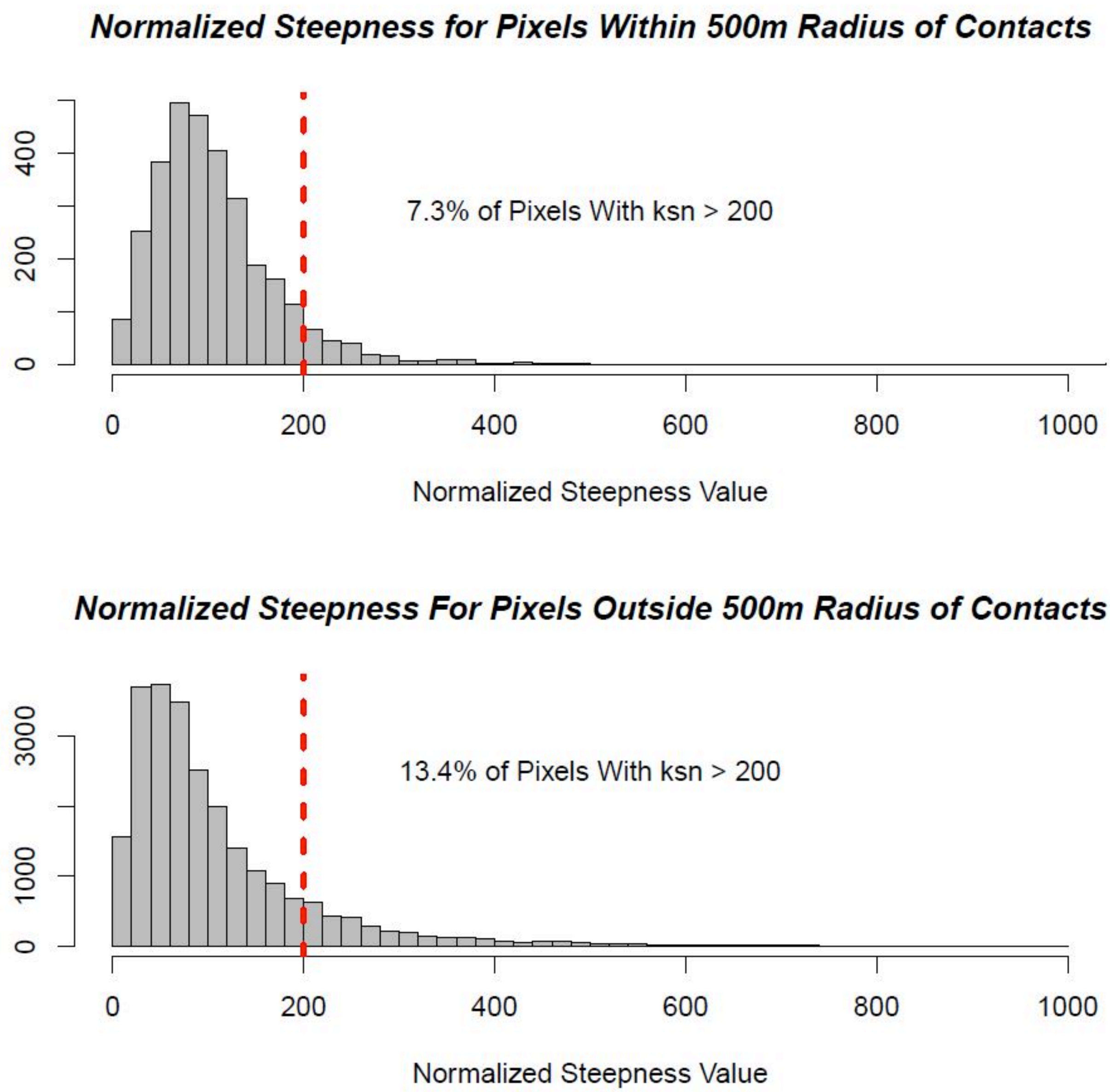

Figure 4. Distribution of normalized steepness values (k_{sn}) for stream pixels within the Athabasca River watershed upstream of Hinton, AB. Streams included in analysis exceed a minimum upstream drainage area of 2.5 km^2. (A) Distribution for pixels within a 500m radius of major lithologic contacts identified at 1:1,000,000 scale. (B) Distribution of all remaining pixels beyond specified 500m radius.

Although lithologic boundaries do not determine knickzone location on a regional scale, clear differences in channel form exist between catchments across the three physiographic provinces. Figure 5 compares representative first-order stream catchments from each of the three physiographic provinces in the study area. For each basin, the 1:50,000-scale geology is overlain onto a contoured 18m DEM image. The main stream is colorized according to normalized steepness value. Figure 5A shows a bedrock river in the Main Ranges. The area of increased channel steepness is a major knickzone. At its maximum value, k_{sn} exceeds $300m^{0.9}$. Upon its confluence with the trunk stream, channel steepness decreases as the stream leaves the zone of perturbation. In Figure 5B, a bedrock river in the Front Ranges exhibits a similar knickzone located just above the confluence with the trunk stream. However, both the spatial extent and steepness magnitude of this channel are lesser than observed for the Main Range bedrock river, with peak values near $250m^{0.9}$. However, both the spatial extent and steepness magnitude of this channel are lesser than observed for the Main Range bedrock river. Figure 5C shows a representative channel in the Foothills. Although channel steepness does fluctuate slightly along profile, the corresponding k_{sn} magnitudes are uniformly low and never exceed $100m^{0.9}$. The notable knickzone near the channel mouth in Main and Front Range streams does not exist here.

Expanding upon the observed relationship between channel form and physiographic province, normalized channel steepness (k_{sn}) values for bedrock streams in the 30 selected study catchments show regionally distinct patterns of knickzone extent and magnitude (Figure 6). Greater variations in k_{sn} along the channel profile suggest more substantial deviation from equilibrium form. We found that k_{sn} values are highly variable for Main Range and Front Range bedrock rivers but are essentially constant in Foothills streams. These findings reveal a major external force generating large knickzones in alpine catchments. These knickzones are most

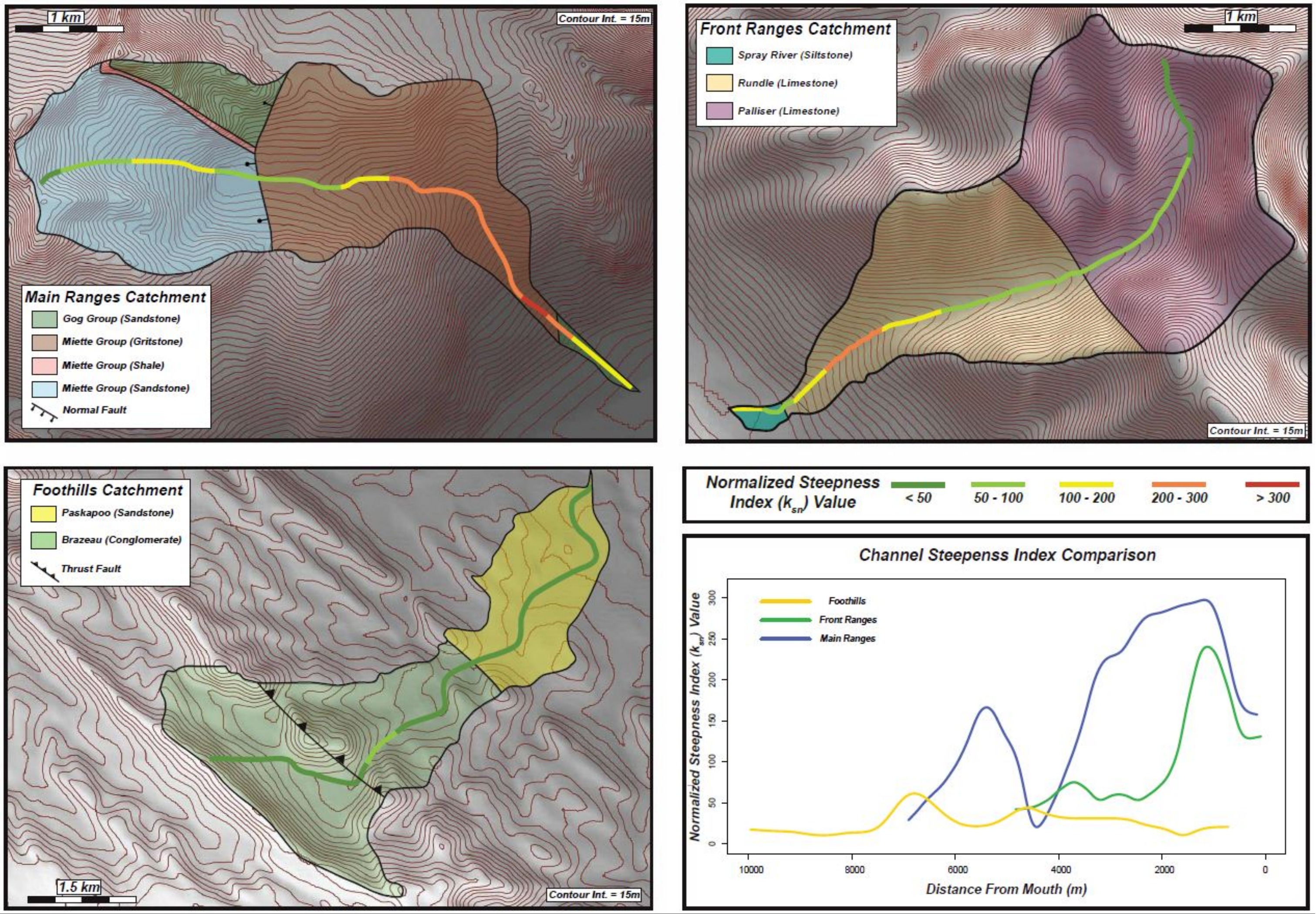

Figure 5. Representative first-order stream catchments for all physiographic provinces. (A) Stream in the Main Ranges that flows over a major glacial hanging valley. (B) Stream in the Front Ranges that shows a comparably less pronounced glacial hanging valley. (C) Stream in the Foothills that is unperturbed from equilibrium form. (D) Channel steepness vs. distance from mouth for each representative stream.

pronounced in the Main Range streams, as demonstrated by the extreme magnitudes of variability in k_{sn} between 1 and 4 km upstream of channel mouth, with peak k_{sn} values exceeding $500m^{0.9}$ (Figure 6; blue lines). These knickzones are also visible in the Front Range bedrock rivers, though its peak k_{sn} values (~$250m^{0.9}$) and spatial extent are smaller than in the Main Range catchments (Figure 6; green lines). Notably, these knickzones does not exist in the Foothills streams, where k_{sn} values rarely exceed $50m^{0.9}$ and never surpass $100m^{0.9}$ (Figure 6; gold lines). This result suggests that the source of perturbation present in the alpine catchments of the Main and Front Ranges does not affect the Foothills.

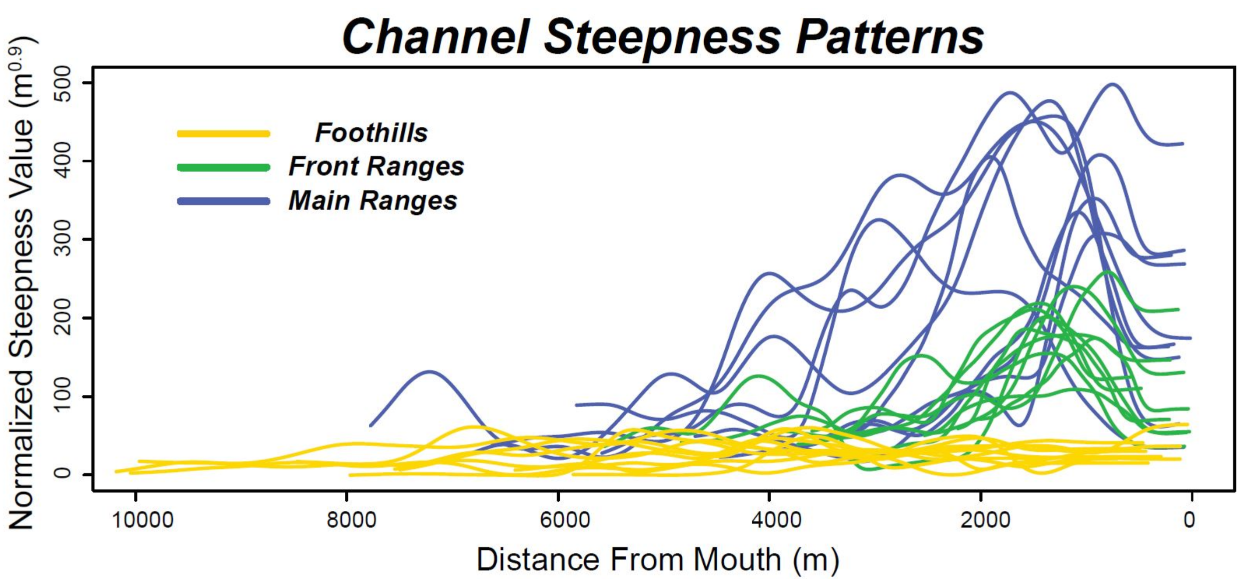

Figure 6. Along-channel normalized channel steepness value (k_{sn}) for 30 first-order streams in the Athabasca River watershed. Plot displays channels from mouth (right of figure) to headwaters (left of figure; stream lengths are variable). Main Ranges (blue) and Front Ranges (green) streams show a pronounced deviation from equilibrium form as evidenced by highly variable k_{sn} values. Foothills streams show little fluctuation in k_{sn}, suggesting that these streams are in equilibrium form.

6. DISCUSSION AND CONCLUSIONS

6.1 Regional Controls on Channel Morphology

The synthesis of rock erodibility data and bedrock river normalized steepness patterns suggests a fundamental relationship between bedrock geology, glacial preconditioning, and modern fluvial geomorphology. Field-quantified bedrock strength suggests that distinct patterns of erodibility exist within and between the major physiographic provinces. These regional erodibility contrasts support the hypothesis that long-timescale differential erosion has created a landscape in which modern mountain topography is adjusted to bedrock strength (Osborn et al., 2006). Thus, our data support the hypothesis that bedrock strength may be a primary control on topographic evolution in the Canadian Rockies over million-year timescales.

On the shorter timescales relevant to the fluvial system, however, these bedrock strength differences do not appear to substantially affect channel morphology and patterns of erosion in the Athabasca watershed. The lack of significant increases in k_{sn} values at or near lithologic contacts implies that no strong relationship exists between local variations in bedrock geology and the presence of major knickzones. It is therefore unlikely that fluvial incision is focused at lithologic contacts. Indeed, the most iconic waterfalls in the region – Athabasca Falls and Sunwapta Falls – are developed within homogenous bedrock far removed from contacts and may have been created by block plucking during glacial retreat (Mountjoy and Price, 2003). We argue that localized variations in bedrock erodibility are not a regionally important first-order control on fluvial form and process.

This finding complicates the seemingly straightforward relationship between rock strength and long-term physiographic development in the Canadian Rocky Mountains. Although lithology dominates patterns of erosion over the lifespan of the orogen (Osborn et al., 2006), the processes active on shorter timescales are more dynamic and complex. Our analysis of normalized channel steepness shows that streams in this area are in a state of disequilibrium. The inability of bedrock geology to adequately explain this observation suggests that some other source of perturbation is disturbing these rivers from equilibrium form.

Combining field observations, DEM analysis, and knowledge of regional Quaternary history, we interpret the major deviations from equilibrium channel form to be glacial in origin. Specifically, we suggest that the major knickzones seen in the Main Range and Front Range bedrock rivers (though conspicuously absent in Foothills rivers) are the expression of the glacially carved hanging valleys characteristic of the Canadian Rockies. The sudden elevation change between tributary streams and trunk rivers focuses incision in these oversteepened reaches (Figure 7). In channel steepness analysis, this knickzone is commonly situated at ~1 to 4 kilometers from the confluence, consistent with the normal location of a hanging valley relative to the modern trunk river valley (Amundson and Iverson, 2006). The morphology of the fluvial network that presently occupies this landscape in the Main and Front Ranges of the Canadian Rockies is fundamentally controlled by this antecedent glacial system.

Figure 7. Typical first-order bedrock channel incising a gorge as it flows over a glacial hanging valley. Photograph taken in the Main Ranges from Highway 93 facing west.

It is important to note that no hanging valley knickzones (zones of channel steepness exceeding $100m^{0.9}$) are displayed in Foothills catchments. The thick cover of young, erodible sedimentary rock exposed at the surface here is incapable of supporting steep slopes or mountainous topography. Additionally, the lack of significant geologic structure east of the orogen-bounding thrust suggests that the Foothills were not substantially uplifted or deformed like the rock of the Main and Front Ranges. Previous work shows that this province was hilly well before recent glaciation (Osborn et al., 2006). Because the Foothills were not mountainous during the Holocene and experienced no alpine glaciation, these streams contain no recognizable alpine glacial signature.

The presence of the glacial hanging valley knickzone is apparent in both the Front and Main Ranges, though its expression is somewhat different across the two physiographic provinces. In the Main Ranges, hanging valley knickzones show extremely variable k_{sn} values that reach high magnitudes over a wide spatial extent. By contrast, the prominent knickzones in the Front Ranges reach lower overall k_{sn} values and are more tightly constrained in space. Despite a similar glacial history, the interaction between the inherited landscape and modern fluvial form are different.

We believe that this discrepancy in hanging valley knickzone form is primarily driven by province-scale contrasts in bedrock strength. Though channel form is not affected by rock erodibility at the scale of individual contacts, Schmidt Hammer data shows that mean bedrock strength is significantly greater (p-value $< 2.2 \times 10^{-16}$) in the Main Ranges than in the Front Ranges. The old, hard, well-indurated rock of the Main Ranges is extremely resistant to channel incision and preserves the signal of glacial imprinting over long timespans. The Front Ranges bedrock is weaker and will not preserve the glacial signal over comparable durations. As such, channel incision is more efficient in the Front Ranges and the evidence of glacial imprint is eroded from the landscape at an accelerated pace.

6.2 Future Landscape Evolution

Previous studies have attempted to quantify the duration over which glacial influence will endure in the Canadian Rockies and adjacent regions. Such studies have largely focused on the reworking of glacial sediment in the paraglacial environment (e.g. Slaymaker and McPherson, 1977; Church and Slaymaker, 1989; Church et al, 1989; Brardinoni and Hassan, 2007). A reasonable estimate for the longevity of paraglacial conditions throughout all of Canada based upon sediment load is 10^5 years (Ashmore, 1993). However, local flux in the Rockies is more difficult to constrain because multiple Neoglacial advances have complicated the sedimentary record (Brooks, 1994). While these fluctuations do not substantially change estimates for long-term landscape evolution, they may disproportionately affect geomorphology in first-order alpine catchments such as those examined in this study.

The overwhelming signal of glacial influence in the montane portion of the Athabasca River watershed is likely present throughout the Canadian Cordillera (Bobrowsky and Rutter, 1992; Ashmore, 1993). As such, it is reasonable to predict that regional landscape evolution over the next several thousand years will be focused primarily on the transition from a glacial to fluvial erosive signature (Church and Ryder, 1972). Our data suggest that bedrock rivers in the study area focus incision where a geomorphic mismatch exists between glacial and fluvial process. The long-term result of this erosive regime will be the reshaping of the alpine landscape toward a more characteristically fluvial morphology (Braun, 1999; Montgomery, 2002). Hillslope mass wasting and subsequent fluvial transport drive this evolution. The rate at which this transition will progress may range anywhere from 100ka to more than 500ka (Dadson and Church, 2005; Hobley et al., 2010).

Across the Canadian Rockies, relaxation from glacial influence will be controlled at least in part by variations in rock erodibility across the orogen. Extreme resistance to erosion in the Main Ranges will delay the restoration of V-shaped valleys, while this process will be comparably faster in the Front Ranges. However, future Neoglacial fluctuations may maintain a glacial erosive regime in the highest alpine reaches of both ranges, delaying indefinitely the complete restoration of fluvial valleys. The Foothills, currently in relative geomorphic equilibrium, will likely retain their present geomorphic character over these timescales.

6.3 Conclusions

Our findings demonstrate that glacial imprinting is the dominant control on patterns of river erosion in the modern Canadian Rocky Mountains. Although bedrock geology does not control fluvial geomorphology at the scale of lithologic boundaries, strength contrasts across the three physiographic provinces control the preservation of glacial landforms across the region. Though the presence of hanging valleys and other glacial landforms is well documented in this region, their overwhelming significance in controlling channel form of montane streams in the Athabasca River Watershed highlights the importance of lingering glacial signals in the Canadian Rockies.

Recognizing this first-order control of glacial imprinting on modern fluvial geomorphology has implications for the broader study of post-orogenic mountain environments. An enduring mystery in geomorphology is the mismatch between calculated erosion rates in active orogenic systems and the enduring lifespan of passive mountain belts (Bishop, 2010; Egholm, 2013). An enhanced understanding of fluvial erosion patterns in tectonically inactive orogens may contribute to improved landscape evolution modeling. Additionally, mountain systems such as the Canadian Rockies serve as distant-future analogues for modern uplifts such as the Andes. Constraining the erosive history of passive orogens may lend greater predictive power to long-term estimates for the topographic development of active orogens as they eventually transition toward tectonic quiescence.

APPENDIX 1: FIELD DATA

This dataset compiles all field measurements collected in the vicinity of Jasper Nation Park in Alberta, Canada during Summer 2013. Stations are arranged in chronological order of collection. Locations are recorded with WGS84 coordinates in units of decimal degrees. Formation names were assigned using the 1:1,000,000 scale geologic map (Price et al., 1977).

I.D.	Date	Latitude	Longitude	Formation	Schmidt #s	Scanline	Fracture Spacing
01	7/31/13	53.19984	-117.91840	Bullhead (Lower Cretaceous)	N/A	N/A	N/A
02	7/31/13	53.17753	-117.97148	Spray River (Triassic)	32, 34, 56, 41, 51, 32, 42, 32, 20, 28, 28, 38, 18, 54, 50, 58, 56, 56, 54, 28, 33, 47, 58, 39, 44, 43, 38, 32, 27, 54, 54, 48, 52, 54, 33, 50, 38, 30, 34, 30	13 feet, horizontal	3' 10", 6' 0", 7' 11", 12' 2"
03	7/31/13	53.12793	-117.77441	Fernie (Jurassic)	52, 44, 41, 42, 46, 48, 52, 49, 44, 44, 50, 42, 58, 42, 44, 54, 50, 62, 52, 56, 48, 60, 57, 47, 48, 47, 41, 42, 43, 46, 45, 49, 54, 60, 47, 49, 42, 46, 38, 46	9 feet, horizontal	0' 6", 1' 0", 1' 11", 3' 10", 4' 5", 5' 10", 9' 3"
04	7/31/13	53.14490	-117.78050	Fernie (Jurassic)	45, 48, 56, 58, 49, 52, 58, 56, 45, 58, 60, 48, 42, 48, 42, 39, 52, 46, 48, 55, 42, 42, 62, 66, 62, 58, 54, 57, 58, 42, 55, 52, 51, 51, 53, 42, 42, 42, 51, 41	13 feet, vertical	0' 3", 0' 9", 1' 2", 1' 7", 2' 2", 2' 4", 2' 6", 2' 10", 3' 1", 3' 10", 4' 11", 5' 2", 5' 7", 5' 9", 6' 0", 6' 5", 6' 9", 7' 1", 7' 5", 7' 10", 8' 1", 8' 9", 8' 11", 9' 0", 9' 3", 9' 10", 10' 1", 10' 8", 11' 0", 11' 4", 11' 8", 12' 0", 12' 4", 13' 1"

05	7/31/13	53.17533	-117.83955	Fernie (Jurassic)	32, 51, 43, 40, 32, 60, 59, 57, 57, 59, 55, 55, 45, 42, 51, 53, 54, 56, 57, 46, 40, 60, 60, 58, 44, 45, 45, 50, 66, 59, 60, 50, 52, 55, 50, 54, 42, 55, 40, 42	7 feet, vertical	0' 0", 0' 11", 1' 10", 2' 6", 3' 0", 3' 6", 4' 2", 4' 8", 6' 0"
06	8/1/13	53.19522	-117.90406	Bullhead (Lower Cretaceous)	39, 36, 35, 32, 34, 32, 43, 35, 38, 35, 32, 42, 33, 36, 38, 32, 37, 29, 38, 36, 42, 29, 30, 36, 42, 33, 28, 40, 35, 28, 38, 32, 30, 33, 38, 46, 44, 30, 50, 29	13 feet, horizontal	0' 5", 2' 10", 3' 3", 4' 4", 4' 10", 6' 6", 7' 3", 7' 8", 10' 7", 11' 9"
07	8/1/13	53.19522	-118.07282	Spray River (Triassic)	30, 39, 36, 42, 28, 33, 29, 24, 22, 24, 28, 26, 38, 39, 25, 28, 26, 27, 32, 30, 33, 35, 18, 23, 25, 24, 40, 39, 52, 41, 21, 39, 24, 32, 35, 20, 24, 20, 31, 36	6 feet, vertical	0 ' 3", 0' 5", 0' 9", 0' 11", 1' 2", 1' 5", 2' 3", 2' 7", 2' 11", 3' 8", 3' 11", 4' 3", 4' 7", 5' 0", 5' 5", 5' 11", 6' 0"
08	8/1/13	53.05261	-118.07154	Palliser (Devonian)	56, 41, 48, 38, 43, 47, 51, 48, 41, 50, 50, 44, 45, 48, 44, 53, 41, 50, 54, 51, 43, 56, 44, 40, 48, 56, 43, 59, 51, 47, 40, 56, 52, 58, 48, 56, 55, 47, 45, 62	6 feet, vertical	0' 3", 0' 6", 1' 2", 1' 10", 2' 0", 2' 1", 2' 5", 2' 9", 2' 11", 3' 0", 3' 10", 4' 0", 4' 6", 4' 11", 5' 0", 5' 2", 5' 5", 5' 6", 5' 9", 6' 3"
09	8/1/13	53.19895	-117.92225	Bullhead (Lower Cretaceous)	32, 22, 28, 34, 32, 24, 38, 38, 40, 48, 28, 38, 29, 25, 29, 44, 42, 44, 36, 32, 42, 38, 48, 47, 42, 45, 30, 42, 32, 43, 40, 44, 30, 42, 35, 40, 32, 35, 41, 40	N/A	N/A

10	8/1/13	53.19880	-117.92234	Bullhead (Lower Cretaceous)	40, 36, 40, 30, 35, 36, 30, 45, 41, 40, 25, 39, 36, 45, 34, 41, 40, 40, 36, 37, 43, 40, 32, 30, 35, 34, 38, 33, 26, 39, 32, 34, 36, 37, 32, 25, 20, 36, 33, 28	8 feet, horizontal	0' 0", 0' 7", 1' 6", 2' 0", 2' 8", 3' 2", 3' 10", 4' 5", 5' 1", 5' 10", 6' 8", 7' 3", 7' 6"
11	8/1/13	53. 16653	-117.97532	Palliser (Devonian)	54, 47, 44, 50, 54, 48, 43, 64, 61, 46, 54, 42, 50, 40, 46, 55, 52, 50, 49, 58, 52, 60, 49, 45, 55, 53, 48, 51, 57, 50, 45, 50, 49, 50, 45, 43, 46, 48, 53, 53	8 feet, vertical	0' 0", 1' 2", 1' 8", 2' 9", 3' 5", 5' 2", 5' 6", 6' 11", 7' 2", 7' 9"
12	8/1/13	53.16724	-117.97329	Palliser (Devonian)	46, 48, 49, 55, 53, 55, 58, 51, 50, 42, 44, 54, 50, 65, 58, 58, 60, 45, 56, 58, 62, 61, 63, 59, 57, 56, 52, 65, 63, 59, 55, 53, 49, 57, 60, 55, 59, 60, 49, 62	8 feet, vertical	0' 0", 1' 1", 1' 6", 1' 10", 2' 5", 2' 10", 3' 2", 3' 6", 5' 10", 6' 5", 6' 9", 7' 7"
13	8/1/13	53.08702	-118.02502	Rundle (Permian)	53, 50, 50, 46, 51, 49, 48, 46, 48, 48, 58, 48, 52, 50, 49, 42, 45, 44, 52, 52, 44, 47, 48, 56, 51, 50, 53, 58, 52, 54, 53, 57, 50, 54, 52, 51, 45, 46, 44, 50	11, feet, vertical	0' 0", 0' 3", 0' 6", 0' 7", 0' 9", 1' 1", 1' 3", 1' 9", 2' 0", 2' 5", 2' 7", 2' 10", 3' 0", 3' 4", 3' 5", 3' 9", 3' 11", 4' 5", 4' 11", 5' 2",5' 5", 5' 9", 6' 0", 6' 6", 7' 2", 7' 6", 8' 1", 8' 9", 9' 6", 10' 1", 10' 3", 10' 10"
14	8/1/13	53.04153	-118.08802	Palliser (Devonian)	37, 33, 56, 45, 38, 36, 30, 39, 58, 46, 40, 42, 44, 42, 39, 41, 45, 58, 45, 50, 55, 46, 54, 51, 56, 52, 58, 44, 53, 45, 45, 44, 48, 38, 50, 44, 40, 38, 58, 52	7 feet, vertical	0' 0", 0' 8", 1' 8", 3' 2", 3' 8", 4' 6", 5' 6", 5' 10", 5' 11"

15	8/1/13	52.91780	-118.05354	Miette Group (Precambrian)	47, 41, 48, 45, 49, 43, 39, 48, 39, 45, 47, 41, 48, 47, 49, 42, 41, 44, 49, 46, 55, 49, 44, 46, 45, 48, 42, 40, 62, 52, 58, 60, 62, 45, 52, 64, 44, 56, 58, 50		1 per 8ft
16	8/2/13	52.91733	-118.00653	Rundle (Permian)	34, 30, 58, 38, 50, 35, 34, 40, 40, 39, 40, 42, 43, 39, 45, 42, 43, 35, 36, 40, 46, 39, 46, 47, 48, 39, 31, 45, 40, 45, 43, 39, 45, 38, 40, 36, 37, 39, 35, 40	11 feet, horizontal	0' 0", 1' 10", 2' 2", 3' 10", 4' 8", 5' 0", 7' 3", 8' 0", 8' 11", 10' 11"
17	8/2/13	52.92033	-118.00285	Palliser (Devonian)	38, 42, 36, 46, 52, 43, 55, 56, 58, 45, 50, 38, 37, 55, 56, 37, 52, 50, 45, 49, 45, 48, 49, 55, 55, 50, 50, 42, 52, 62, 46, 40, 43, 52, 48, 43, 46, 45, 53, 50	11 feet, horizontal	0' 0", 1' 10", 2' 2", 3' 10", 4' 8", 5' 0", 7' 3", 8' 0", 8' 11", 10' 11"
18	8/3/13	52.71722	-117.61589	Spray River (Triassic)	36, 42, 36, 32, 43, 62, 39, 38, 35, 39, 44, 41, 33, 41, 39, 38, 52, 48, 45, 51, 36, 32, 28, 40, 49, 36, 36, 42, 30, 28, 39, 38, 37, 33, 35, 30, 39, 36, 33, 33	11 feet, vertical	0' 0", 1' 0", 1' 10", 2' 9", 3' 1", 3' 10", 4' 6", 5' 5", 5' 9", 6' 2", 7' 5", 8' 10", 10' 3", 10' 8"
19	8/3/13	52.71722	-117.61589	Spray River (Triassic)	54, 55, 40, 42, 30, 54, 43, 39, 42, 39, 40, 48, 30, 36, 44, 46, 46, 33, 39, 44, 48, 56, 46, 42, 44, 35, 39, 40, 42, 43, 40, 44, 50, 46, 34, 40, 38, 40, 41, 39	11 feet, vertical	0' 0", 1' 0", 1' 10", 2' 9", 3' 1", 3' 10", 4' 6", 5' 5", 5' 9", 6' 2", 7' 5", 8' 10", 10' 3", 10' 8"

20	8/3/13	52.76879	-117.68496	Gog (Cambrian)	51, 52, 58, 46, 46, 52, 50, 52, 62, 50, 61, 52, 63, 48, 53, 56, 56, 58, 56, 52, 50, 50, 60, 58, 59, 51, 57, 55, 50, 59, 60, 53, 56, 58, 60, 65, 53, 54, 61, 58	8 feet horizontal	0' 0", 0' 11", 3' 3", 5' 2", 5' 10", 6' 7", 8' 0"
21	8/3/13	52.78508	-117.68720	Rundle (Permian)	46, 42, 58, 45, 49, 46, 34, 48, 40, 42, 54, 50, 54, 44, 46, 55, 52, 50, 51, 39, 52, 55, 56, 50, 56, 45, 45, 50, 51, 51, 57, 51, 52, 45, 49, 43, 54, 49, 51, 47	8 feet, horizontal	0' 0", 0' 7", 0' 11", 1' 4", 1' 7", 2' 4", 3' 2", 3' 6", 3' 7", 7' 2", 8' 0"
22	8/4/13	52.88093	-118.35069	Miette Group (Precambrian)	49, 51, 50, 48, 50, 50, 49, 46, 46, 54, 51, 44, 45, 45, 43, 40, 49, 38, 52, 35, 46, 47, 40, 45, 52, 46, 58, 40, 43, 50, 48, 50, 45, 46, 45, 43, 52, 49, 49, 50	6 feet, diagonal	0' 0", 1' 8", 2' 0", 2' 9", 2' 11", 3' 6", 4' 1", 4' 5", 4' 8", 5' 2", 5' 6", 5' 11"
23	8/4/13	52.87286	-118.30289	Miette Group (Precambrian)	48, 54, 59, 58, 57, 50, 58, 59, 58, 56, 55, 54, 58, 55, 50, 59, 59, 55, 52, 56, 58, 60, 55, 61, 60, 63, 64, 60, 59, 60, 60, 58, 60, 65, 59, 65, 59, 55, 60, 66	8 feet, horizontal	0' 0", 1' 4", 1' 10", 2' 5", 3' 3", 3' 11", 4' 6", 5' 4", 6' 0", 7' 5"
24	8/4/13	52.87252	-118.29174	Miette Group (Precambrian)	33, 32, 35, 34, 35, 35, 36, 30, 33, 31, 30, 30, 36, 30, 35, 30, 32, 30, 29, 36, 30, 30, 35, 31, 33, 25, 28, 31, 29, 33, 28, 31, 30, 38, 25, 31, 28, 36, 35, 36	15 feet, diagonal	0' 0", 2' 2", 5' 8", 11' 6", 14' 6"

25	8/4/13	52.86647	-118.24937	Miette Group (Precambrian)	58, 55, 55, 50, 60, 58, 63, 50, 50, 55, 57, 50, 50, 49, 56, 59, 50, 50, 51, 49, 53, 48, 52, 58, 52, 49, 55, 49, 2, 58, 51, 51, 60, 63, 50, 59, 60, 63, 60, 52	15 feet	0' 0"
26	8/4/13	52.86254	-118.21318	Miette Group (Precambrian)	49, 51, 49, 55, 54, 50, 49, 51, 56, 52, 51, 55, 46, 47, 51, 51, 58, 55, 56, 51, 48, 54, 57, 55, 50, 51, 49, 55, 50, 55, 50, 51, 45, 45, 54, 45, 56, 55, 56, 49	20 feet	20' 0"
27	8/4/13	52.86060	-118.18167	Miette Group (Precambrian)	50, 50, 55, 50, 45, 49, 49, 50, 48, 51, 48, 50, 45, 55, 49, 48, 51, 59, 55, 60, 50, 55, 56, 50, 45, 49, 54, 49, 47, 47, 45, 52, 48, 50, 51, 45, 49, 55, 50, 49	13' 5" horizontal	0' 4", 3' 1", 4' 5", 7' 9", 9' 10", 13' 0"
28	8/4/13	52.86060	-118.18167	Miette Group (Precambrian)	23, 24, 23, 25, 20, 19, 22, 24, 20, 22, 18, 12, 15, 19, 15, 23, 22, 19, 23, 23, 22, 18, 21, 19, 23, 20, 22, 24, 19, 22, 18, 20, 19, 15, 21, 20, 22, 18, 19, 20	10 feet, horizontal	0' 0", 0' 10", 1' 5", 1' 11", 2' 6", 2' 10", 3' 5", 3' 9", 4' 4", 5' 3", 5' 6", 6' 2", 7' 5", 8' 1", 8' 8", 9' 6"
29	8/4/13	52.85735	-118.13426	Miette Group (Precambrian)	19, 20, 15, 18, 20, 18, 15, 15, 21, 17, 20, 19, 18, 21, 20, 15, 17, 16, 20, 12, 20, 20, 19, 20, 18, 18, 21, 18, 19, 19, 17, 20, 17, 19, 20, 14, 19, 18, 18, 18		

30	8/4/13	52.86200	-118.10952	Miette Group (Precambrian)	56, 50, 65, 56, 53, 52, 62, 59, 63, 57, 58, 50, 51, 49, 55, 53, 50, 55, 50, 51, 54, 48, 60, 48, 57, 60, 58, 61, 52, 48, 60, 52, 60, 60, 61, 56, 51, 51, 58, 50	10 feet, diagonal	0' 0", 3' 4", 5' 5", 6' 8", 7' 8", 8' 3", 9' 1"
31	8/5/13	52.83014	-118.10952	Miette Group (Precambrian)	50, 55, 49, 60, 58, 59, 63, 50, 57, 60, 66, 68, 61, 58, 65, 65, 63, 64, 53, 65, 62, 65, 59, 53, 66, 55, 60, 63, 63, 66, 60, 64, 49, 60, 58, 62, 59, 63, 61, 65	7 feet, horizontal	0' 0", 0' 5", 1' 0", 1' 3", 2' 6", 3' 5", 5' 7"
32	8/5/13	52.82866	-118.12783	Miette Group (Precambrian)	20, 18, 19, 18, 17, 16, 15, 20, 18, 15, 15, 15, 20, 18, 15, 22, 21, 19, 17, 15, 18, 20, 21, 25, 23, 24, 20, 22, 19, 15, 20, 19, 15, 16, 19, 21, 18, 19, 18, 17	6 feet, horizontal	0' 0", 1' 3", 2' 0", 3' 4", 4' 1", 4' 10", 5' 5"
33	8/5/13	52.82723	-118.13531	Miette Group (Precambrian)	16, 15, 15, 16, 14, 15, 12, 14, 15, 14, 12, 20, 15, 14, 14, 19, 18, 18, 12, 15, 14, 15, 21, 19, 14, 17, 15, 14, 19, 16, 15, 18, 21, 20, 12, 16, 19, 18, 15, 15	6 feet, horizontal	0' 0", 1' 3", 2' 0", 3' 4", 4' 1", 4' 10", 5' 5"
34	8/5/13	52.82641	-118.13982	Miette Group (Precambrian)	49, 50, 49, 46, 49, 48, 48, 46, 40, 49, 60, 48, 55, 46, 47, 52, 45, 50, 58, 55, 61, 48, 49, 56, 52, 51, 54, 53, 57, 58, 53, 50, 56, 50, 47, 59, 61, 56, 55, 58	6 feet, horizontal	0' 0", 0' 3", 0' 5", 2' 3", 4' 9"

35	8/5/13	52.82884	-118.14052	Miette Group (Precambrian)	50, 50, 49, 48, 51, 49, 51, 52, 48, 51, 46, 48, 53, 52, 51, 47, 46, 49, 51, 48, 50, 50, 52, 48, 51, 46, 50, 52, 48, 46, 41, 49, 52, 47, 54, 53, 49, 53, 50, 46	5 feet, horizontal	0' 4", 0' 9", 1' 0", 1' 5", 1' 10", 1' 11", 2' 6", 2' 10", 3' 7", 4' 1", 4' 6", 4' 11"
36	8/6/13	52.20898	-117.23329	Eldon (Cambrian)	60, 59, 53, 60, 55, 61, 50, 62, 58, 59, 54, 56, 54, 57, 61, 59, 58, 60, 59, 56, 54, 60, 58, 59, 56, 49, 59, 57, 60, 65, 63, 64, 59, 60, 60, 62, 63, 57, 65, 64	3 feet	0' 8", 1' 6", 2' 4"
37	8/6/13	52.21030	-117.23375	Eldon (Cambrian)	50, 60, 55, 59, 52, 55, 59, 58, 60, 58, 60, 59, 61, 60, 58, 60, 55, 55, 59, 58, 60, 58, 57, 56, 54, 58, 60, 62, 63, 60, 65, 64, 65, 64, 60, 55, 62, 60, 61, 57	5 feet, horizontal	0' 0", 1' 2", 3' 8", 4' 1", 4' 9", 5' 0"
38	8/6/13	52.24736	-117.26542	Eldon (Cambrian)	53, 55, 60, 58, 60, 60, 52, 61, 58, 45, 59, 58, 58, 61, 57, 60, 59, 62, 58, 61, 55, 56, 61, 59, 55, 61, 60, 59, 64, 56, 50, 53, 57, 57, 59, 55, 52, 57, 60, 58	[same as KQ-36]	
39	8/7/13	52.68141	-118.04933	Gog (Cambrian)	60, 64, 58, 57, 55, 60, 58, 57, 56, 60, 66, 55, 48, 62, 68, 59, 62, 60, 63, 62, 61, 65, 63, 65, 55, 59, 60, 63, 58, 52, 63, 60, 57, 63, 60, 60, 50, 61, 57, 58		

40	8/7/13	52.76671	-117.99751	Miette Group (Precambrian)	48, 53, 45, 50, 55, 59, 48, 59, 49, 48, 58, 47, 50, 55, 58, 57, 49, 47, 55, 50, 60, 48, 53, 58, 59, 51, 43, 49, 55, 49, 54, 60, 48, 59, 53, 55, 54, 52, 57, 43	5 feet, horizontal	0' 0", 0' 2", 1' 9", 2' 11", 4' 0", 5' 0"
41	8/7/13	52.66525	-117.88160	Gog (Cambrian)	63, 65, 62, 51, 61, 50, 49, 64, 56, 60, 60, 58, 66, 60, 58, 45, 59, 66, 62, 64, 61, 63, 63, 60, 60, 63, 62, 61, 52, 67, 61, 61, 65, 70, 60, 60, 63, 62, 61, 60	10 feet, horizontal	0' 0", 5' 3", 9' 8"
42	8/7/13	52.66525	-117.88160	Gog (Cambrian)	55, 65, 58, 60, 62, 62, 66, 64, 60, 65, 62, 63, 64, 60, 50, 57, 60, 61, 60, 58, 50, 51, 60, 55, 60, 58, 60, 59, 62, 64, 60, 60, 64, 62, 64, 50, 60, 55, 58, 62	[same as KQ-41]	
43	8/7/13	52.53238	-117.64463	Eldon (Cambrian)	49, 46, 40, 42, 47, 50, 42, 45, 45, 48, 45, 44, 40, 47, 43, 40, 40, 44, 50, 46, 47, 43, 46, 47, 39, 46, 40, 47, 40, 46, 47, 47, 43, 40, 41, 45, 49, 46, 40, 39	10 feet horizontal	0' 0", 0' 8", 1' 0", 1' 6", 2' 3", 3' 0", 3' 10", 4' 5", 5' 0", 5' 4", 6' 6", 6' 10", 7' 8", 8' 1", 9' 5"
44	8/7/13	52.68049	-117.87132	Gog (Cambrian)	70, 69, 67, 70, 69, 71, 64, 63, 65, 66, 67, 68, 68, 66, 70, 69, 68, 70, 67, 65, 67, 70, 67, 68, 68, 67, 68, 68, 68, 67, 67, 66, 66, 67, 62, 62, 65, 58, 67, 66	5 feet, horizontal	0' 0", 0' 9", 4' 6"

45	8/10/13	53.54143	-116.99100	Paskapoo (Paleogene)	28, 35, 34, 30, 29, 35, 38, 28, 34, 27, 35, 33, 35, 38, 24, 22, 20, 23, 25, 24, 23, 22, 21, 22, 22, 23, 23, 20, 20, 27, 18, 21, 23, 24, 29, 28, 22, 25, 29, 21	N/A	N/A
46	8/10/13	53.55551	-117.39812	Paskapoo (Paleogene)	15, 19, 28, 29, 26, 28, 27, 30, 24, 27, 26, 21, 27, 20, 21, 20, 20, 28, 35, 25, 24, 28, 23, 18, 20, 26, 25, 30, 29, 26, 27, 23, 31, 29, 28, 28, 29, 15, 32, 27	5 feet, horizontal	0' 0", 0' 8", 1' 4", 1' 9", 2' 2", 2' 7", 3' 0", 3' 11", 4' 9"
47	8/10/13	53.32169	-117.69856	Brazeau (Late Cretaceous)	25, 25, 24, 26, 33, 35, 37, 33, 38, 30, 31, 25, 40, 28, 39, 35, 34, 40, 20, 28, 19, 22, 42, 39, 28, 33, 32, 19, 30, 29, 27, 36, 38, 30, 40, 23, 35, 34, 37, 40	6 feet, horizontal	0' 0", 1' 4", 1' 10", 2' 9", 3' 5", 4' 10", 5' 0"
48	8/10/13	53.32341	-117.69146	Alberta (Cretaceous)	44, 43, 44, 42, 35, 48, 45, 42, 46, 45, 46, 37, 48, 47, 42, 42, 45, 55, 49, 42, 38, 52, 46, 48, 50, 48, 38, 47, 44, 51, 35, 40, 44, 32, 41, 48, 41, 49, 42, 46	6 feet, vertical	0' 0", 0' 8", 1' 9", 2' 0", 2' 3", 3' 1", 3' 6", 4' 4", 5' 1"
49	8/10/13	53.24000	-117.78945	Fernie (Jurassic)	38, 36, 25, 30, 25, 26, 29, 25, 30, 36, 19, 25, 24, 27, 38, 33, 39, 45, 37, 38, 32, 36, 36, 20, 34, 33, 32, 45, 15, 21, 20, 22, 27, 26, 31, 38, 30, 32, 30, 24	4 feet, diagonal	0' 0", 0' 4", 0' 11", 1' 2", 1' 3", 1' 8", 2' 0", 2' 5", 2' 9", 3' 0"

50	8/10/13	53.24000	-117.78945	Fernie (Jurassic)	62, 63, 64, 58, 56, 64, 62, 61, 65, 62, 62, 63, 65, 62, 63, 61, 58, 64, 64, 66, 45, 50, 49, 57, 56, 61, 55, 54, 57, 55, 58, 57, 60, 48, 61, 50, 59, 58, 60, 58	5 feet, vertical	0' 0", 0' 9",1' 3", 1' 8", 2' 11", 3' 5", 4' 1", 4' 10"
51	8/11/13	52.91926	-118.09380	Miette Group (Precambrian)	48, 50, 55, 40, 42, 45, 47, 46, 43, 55, 60, 50, 53, 40, 48, 39, 44, 50, 56, 45, 44, 45, 32, 41, 44, 40, 42, 40, 41, 41, 37, 44, 45, 51, 40, 39, 46, 40, 38, 52	6 feet, horizontal	0' 0", 0' 3", 0' 8", 0' 9", 1' 5", 1' 10", 2' 4", 2' 5", 3' 1", 3' 11", 4' 2", 4' 4", 4' 10", 5' 7"
52	8/11/13	52.91742	-118.08065	Miette Group (Precambrian)	45, 45, 38, 39, 45, 44, 43, 48, 50, 44, 36, 43, 51, 49, 40, 41, 52, 38, 51, 46, 48, 40, 50, 43, 47, 41, 44, 42, 43, 46, 40, 57, 44, 48, 39, 47, 39, 50, 46, 47		
53	8/12/13	52.59689	-117.93593	Gog (Cambrian)	57, 49, 50, 61, 52, 60, 59, 50, 60, 63, 50, 49, 66, 61, 60, 54, 63, 58, 57, 62, 66, 63, 62, 65, 63, 55, 65, 60, 61, 66, 62, 60, 65, 62, 66, 60, 60, 66, 58, 65	10 feet, diagonal	0' 0", 4' 2", 9' 11"
54	8/13/13	52.21968	-117.19070	Lyell (Cambrian)	55, 53, 58, 58, 60, 63, 62, 60, 53, 50, 49, 61, 59, 55, 50, 62, 57, 54, 53, 59, 53, 54, 63, 57, 56, 49, 58, 60, 61, 52, 50, 57, 48, 60, 54, 47, 59, 45, 60, 55	10 feet, horizontal	0' 0", 1' 3"

55	8/13/13	52.26783	-117.28579	Lyell (Cambrian)	55, 50, 54, 57, 56, 52, 54, 48, 62, 63, 63, 65, 54, 53, 51, 56, 61, 55, 50, 60, 52, 56, 52, 49, 62, 44, 49, 61, 55, 56, 48, 53, 56, 48, 43, 60, 53, 56, 58, 41	5 feet, horizontal	0' 0", 0' 9", 1' 5", 2' 4", 2' 10", 3' 3", 3' 5", 3' 11", 4' 8", 4' 10", 4' 11"

APPENDIX 2: DEM DATA

Listed below are along-channel normalized steepness values for 30 study catchments in the three physiographic provinces – Main Ranges, Front Ranges, and Foothills. Distances are recorded from the channel mouth (minimum value) to the headwaters (maximum value). To avoid artificial spikes in channel steepness at confluences, some streams are truncated upstream of their junction with the trunk river (i.e. measurements begin at some distance greater than 0m).

Main Ranges 1		Main Ranges 2		Main Ranges 3	
k_{sn} Values ($m^{0.9}$)	Upstream Distance (m)	k_{sn} Values ($m^{0.9}$)	Upstream Distance (m)	k_{sn} Values ($m^{0.9}$)	Upstream Distance (m)
166	174	269	74	286	78
166	192	269	92	286	104
166	218	269	110	286	122
166	243	269	129	286	148
166	261	269	147	286	174
166	287	269	166	286	200
166	312	269	184	286	226
166	338	269	202	286	252
166	363	269	228	286	278
166	389	269	247	286	304
166	414	269	265	286	323
166	440	269	284	286	341
166	465	269	302	286	360
166	491	269	328	286	378
166	516	269	354	286	396
166	542	269	380	286	415
166	567	269	406	286	433
166	593	269	432	286	452
166	618	269	458	286	470
166	644	269	484	286	488
166	669	269	510	286	507
271	695	269	528	286	525
271	720	269	554	286	544
271	746	304	580	286	562
271	771	304	606	286	580
271	797	304	632	396	599
271	822	304	651	396	617
271	848	304	677	396	636
271	873	304	695	396	654
271	899	304	721	396	672
271	924	304	740	396	691
340	950	304	766	396	709
340	975	304	784	396	728
340	1001	304	810	396	746
340	1026	304	828	396	764
340	1052	304	847	396	783
340	1077	304	865	396	809
340	1095	304	884	396	827

340	1121	304	902	403	853
340	1146	304	920	403	879
340	1164	304	939	403	898
340	1182	304	957	403	924
289	1200	304	976	403	942
289	1226	304	994	403	960
289	1251	304	1012	403	979
289	1277	304	1031	403	997
289	1295	304	1049	403	1016
289	1320	304	1075	403	1034
289	1346	231	1101	403	1060
289	1371	231	1127	403	1086
289	1397	231	1153	312	1112
289	1422	231	1179	312	1130
187	1448	231	1198	312	1156
187	1466	231	1216	312	1182
187	1484	231	1234	312	1201
187	1502	231	1253	312	1219
187	1520	231	1271	312	1238
187	1538	231	1297	312	1256
187	1563	231	1316	312	1282
187	1581	128	1334	312	1300
187	1599	128	1352	312	1326
187	1617	128	1371	200	1352
187	1635	128	1389	200	1378
187	1653	128	1408	200	1404
187	1671	128	1426	200	1423
160	1689	128	1444	200	1449
160	1707	128	1463	200	1467
160	1725	128	1481	200	1486
160	1743	128	1500	200	1504
160	1761	128	1518	200	1522
160	1787	128	1544	200	1541
160	1812	128	1570	200	1567
160	1838	127	1596	200	1593
160	1856	127	1622	141	1619
160	1881	127	1640	141	1645
160	1907	127	1659	141	1671
160	1932	127	1677	141	1689
119	1958	127	1696	141	1708
119	1976	127	1722	141	1726
119	2001	127	1740	141	1744
119	2019	127	1758	141	1770
119	2037	127	1784	141	1789
119	2063	127	1803	141	1815
119	2088	127	1821	141	1841
119	2106	121	1840	127	1867
119	2124	121	1858	127	1893
119	2142	121	1876	127	1911
119	2168	121	1895	127	1930
74	2193	121	1913	127	1948
74	2219	121	1932	127	1966
74	2244	121	1950	127	1992
74	2270	121	1976	127	2011
74	2295	121	2002	127	2037
74	2321	121	2028	127	2055

74	2346	121	2054	127	2074
74	2364	121	2072	99	2092
74	2390	104	2091	99	2110
74	2415	104	2109	99	2129
74	2433	104	2128	99	2155
49	2451	104	2146	99	2181
49	2469	104	2172	99	2207
49	2495	104	2198	99	2233
49	2513	104	2224	99	2259
49	2538	104	2250	99	2285
49	2564	104	2276	99	2311
49	2589	104	2294	99	2337
49	2607	104	2313	68	2355
49	2633	94	2339	68	2381
49	2658	94	2357	68	2407
49	2684	94	2376	68	2426
57	2709	94	2394	68	2444
57	2735	94	2412	68	2462
57	2760	94	2431	68	2481
57	2786	94	2449	68	2499
57	2811	94	2468	68	2525
57	2837	94	2486	68	2551
57	2855	94	2504	68	2577
57	2880	94	2530	56	2603
57	2906	94	2556	56	2629
57	2931	73	2582	56	2648
66	2957	73	2608	56	2666
66	2982	73	2634	56	2692
66	3008	73	2653	56	2710
66	3033	73	2679	56	2729
66	3059	73	2697	56	2747
66	3084	73	2716	56	2766
66	3110	73	2734	56	2784
66	3135	73	2752	56	2802
66	3161	73	2778	56	2821
66	3186	73	2804	69	2839
49	3212	55	2830	69	2858
49	3237	55	2856	69	2876
49	3263	55	2882	69	2894
49	3288	55	2901	69	2913
49	3314	55	2919	69	2931
49	3339	55	2938	69	2950
49	3357	55	2956	69	2968
49	3375	55	2974	69	2986
49	3401	55	2993	69	3005
49	3426	55	3019	69	3023
		55	3037	69	3049
		55	3063	69	3068
		53	3089	69	3086
		53	3115	67	3104
		53	3141	67	3123
		53	3160	67	3141
		53	3178	67	3167
		53	3196	67	3193
		53	3215	67	3212
		53	3233	67	3238

		53	3252	67	3264
		53	3270	67	3290
		53	3288	67	3308
		53	3314	67	3326
				48	3345
				48	3371
				48	3397
				48	3423
				48	3449
				48	3475
				48	3493
				48	3512
				48	3538
				48	3564
				48	3590
				33	3616
				33	3642
				33	3668
				33	3686
				33	3704
				33	3723
				33	3741
				33	3760
				33	3778
				33	3804
				33	3830
Main Ranges 4		**Main Ranges 5**		**Main Ranges 6**	
k_{sn} Values ($m^{0.9}$)	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**
152	126	179	18	68	126
152	144	179	37	68	144
152	162	179	55	68	162
152	181	179	74	68	181
152	199	179	92	68	207
152	218	179	110	68	225
152	236	179	129	68	244
152	254	179	155	68	262
152	273	179	181	68	280
152	291	179	207	68	299
152	317	179	233	68	317
152	336	179	259	68	336
152	362	179	285	68	354
152	388	179	311	68	372
152	414	179	337	68	398
152	432	179	363	68	424
152	458	179	389	68	450
152	484	179	407	68	476
152	510	179	433	68	502
152	536	179	459	68	521
152	562	179	485	68	547
152	588	179	511	68	565
152	614	179	537	68	584
203	640	250	563	68	602
203	666	250	589	68	620

203	692	250	615	192	646
203	710	250	641	192	665
203	736	250	667	192	683
203	762	250	693	192	702
203	788	250	719	192	728
203	807	250	745	192	746
203	833	250	771	192	764
203	851	330	797	192	783
203	877	330	823	192	801
389	903	330	849	192	820
389	929	330	875	192	838
389	955	330	901	192	856
389	981	330	927	192	875
389	1007	330	953	429	893
389	1026	330	979	429	912
389	1052	330	1005	429	930
389	1078	330	1031	429	948
389	1104	417	1057	429	967
389	1130	417	1083	429	985
493	1156	417	1109	429	1004
493	1182	417	1135	429	1022
493	1208	417	1161	429	1040
493	1234	417	1187	429	1059
493	1260	417	1213	429	1077
493	1286	417	1239	429	1096
493	1312	417	1265	429	1114
493	1338	451	1291	450	1132
493	1364	451	1317	450	1151
455	1382	451	1343	450	1169
455	1408	451	1369	450	1188
455	1426	451	1388	450	1206
455	1445	451	1406	450	1224
455	1471	451	1424	450	1243
455	1497	451	1450	450	1261
455	1523	451	1469	450	1280
455	1549	451	1487	450	1298
455	1575	451	1506	450	1324
455	1593	451	1532	450	1350
455	1612	444	1558	450	1376
455	1630	444	1576	448	1394
409	1648	444	1594	448	1413
409	1667	444	1620	448	1431
409	1685	444	1639	448	1450
409	1704	444	1657	448	1468
409	1722	444	1676	448	1486
409	1740	444	1694	448	1505
409	1759	444	1712	448	1523
409	1777	444	1738	448	1542
409	1796	444	1764	448	1560
409	1814	418	1790	448	1578
409	1832	418	1816	448	1604
409	1851	418	1835	448	1630
409	1869	418	1861	438	1649
340	1888	418	1879	438	1667
340	1906	418	1898	438	1693
340	1924	418	1916	438	1712

340	1943	418	1942	438	1738
340	1969	418	1968	438	1756
340	1987	418	1986	438	1782
340	2006	418	2012	438	1808
340	2024	418	2031	438	1834
340	2042	364	2057	438	1852
340	2061	364	2075	438	1871
340	2079	364	2101	375	1889
340	2098	364	2127	375	1908
340	2116	364	2146	375	1926
226	2134	364	2172	375	1944
226	2153	364	2198	375	1963
226	2171	364	2216	375	1981
226	2190	364	2234	375	2000
226	2208	364	2253	375	2018
226	2226	364	2271	375	2036
226	2252	349	2290	375	2055
226	2278	349	2308	375	2073
226	2304	349	2326	375	2092
226	2330	349	2345	375	2110
226	2349	349	2371	375	2128
226	2367	349	2389	322	2147
194	2386	349	2408	322	2165
194	2404	349	2434	322	2184
194	2422	349	2460	322	2202
194	2441	349	2478	322	2220
194	2459	349	2496	322	2239
194	2478	349	2515	322	2257
194	2504	349	2533	322	2276
194	2522	385	2552	322	2294
194	2540	385	2570	322	2312
194	2559	385	2588	322	2331
194	2577	385	2607	322	2349
194	2596	385	2633	322	2368
194	2614	385	2651	305	2386
153	2632	385	2670	305	2404
153	2651	385	2696	305	2423
153	2669	385	2722	305	2441
153	2688	385	2740	305	2460
153	2714	385	2758	305	2478
153	2740	385	2784	305	2496
153	2758	386	2810	305	2515
153	2784	386	2836	305	2533
153	2810	386	2862	305	2552
153	2828	386	2888	305	2570
153	2854	386	2914	305	2596
153	2873	386	2940	305	2622
118	2891	386	2959	275	2640
118	2910	386	2985	275	2659
118	2928	386	3011	275	2677
118	2946	386	3037	275	2703
118	2965	310	3063	275	2729
118	2983	310	3081	275	2748
118	3002	310	3107	275	2766
118	3028	310	3126	275	2784
118	3054	310	3144	275	2810

118	3072	310	3170	275	2829
118	3090	310	3196	275	2847
118	3109	310	3214	275	2866
118	3135	310	3233	228	2884
96	3153	310	3259	228	2902
96	3172	310	3277	228	2921
96	3190	250	3296	228	2939
96	3216	250	3322	228	2958
96	3242	250	3348	228	2976
96	3268	250	3366	228	2994
96	3294	250	3384	228	3020
96	3312	250	3403	228	3046
96	3331	250	3421	228	3072
96	3349	250	3440	228	3098
96	3368	250	3458	228	3124
127	3386	250	3484	209	3143
127	3404	250	3510	209	3161
127	3423	250	3536	209	3180
127	3441	240	3562	209	3198
127	3460	240	3588	209	3216
127	3478	240	3606	209	3242
127	3496	240	3625	209	3261
127	3515	240	3643	209	3287
127	3533	240	3662	209	3313
127	3552	240	3680	209	3339
127	3570	240	3698	209	3357
127	3596	240	3717	209	3383
127	3614	240	3735	213	3409
158	3633	240	3761	213	3428
158	3651	240	3780	213	3446
158	3670	233	3798	213	3464
158	3688	233	3816	213	3490
158	3714	233	3835	213	3509
158	3732	233	3853	213	3535
158	3751	233	3879	213	3561
158	3769	233	3898	213	3587
158	3795	233	3924	213	3613
158	3814	233	3950	213	3631
158	3840	233	3968	231	3657
158	3866	233	3986	231	3683
186	3884	233	4005	231	3709
186	3902	233	4023	231	3735
186	3921	195	4042	231	3761
186	3939	195	4060	231	3780
186	3958	195	4078	231	3798
186	3984	195	4097	231	3816
186	4002	195	4123	231	3842
186	4020	195	4149	231	3861
186	4039	195	4167	263	3887
186	4065	195	4186	263	3913
186	4083	195	4204	263	3939
186	4102	195	4222	263	3965
186	4120	195	4241	263	3991
142	4138	195	4267	263	4009
142	4157	117	4293	263	4035
142	4175	117	4319	263	4054

142	4201	117	4337	263	4072
142	4220	117	4363	263	4090
142	4246	117	4389	263	4109
142	4272	117	4415	263	4135
142	4290	117	4441	223	4161
142	4316	117	4467	223	4187
142	4334	117	4486	223	4213
142	4353	117	4512	223	4231
142	4371	117	4530	223	4257
89	4390	93	4548	223	4276
89	4408	93	4567	223	4302
89	4426	93	4593	223	4320
89	4452	93	4619	223	4346
89	4471	93	4637	223	4364
89	4497	93	4656	116	4383
89	4515	93	4682	116	4409
89	4534	93	4700	116	4435
89	4552	93	4718	116	4461
89	4570	93	4744	116	4479
89	4589	93	4763	116	4498
89	4607	93	4789	116	4524
89	4626	85	4815	116	4550
127	4644	85	4841	116	4576
127	4662	85	4867	116	4602
127	4681	85	4885	116	4628
127	4699	85	4904	61	4646
127	4718	85	4922	61	4664
127	4736	85	4940	61	4683
127	4754	85	4959	61	4701
127	4773	85	4985	61	4720
127	4791	85	5011	61	4738
127	4810	85	5037	61	4756
127	4828	49	5055	61	4775
127	4846	49	5081	61	4801
127	4865	49	5107	61	4819
133	4883	49	5133	61	4838
133	4902	49	5159	61	4864
133	4920	49	5185	43	4890
133	4938	49	5211	43	4916
133	4957	49	5237	43	4942
133	4975	49	5263	43	4968
133	4994	49	5289	43	4994
133	5012	24	5315	43	5020
133	5030	24	5341	43	5046
133	5049	24	5360	43	5072
133	5067	24	5378	43	5098
133	5086	24	5396	43	5116
133	5104	24	5415	46	5134
133	5130	24	5433	46	5153
91	5148	24	5452	46	5171
91	5174	24	5478	46	5197
91	5193	24	5496	46	5223
91	5211	24	5514	46	5249
91	5237	24	5533	46	5275
91	5256	19	5559	46	5301
91	5274	19	5585	46	5320

91	5300	19	5603	46	5346
91	5318	19	5622	46	5372
91	5337	19	5640	56	5398
91	5363	19	5658	56	5424
91	5381	19	5684	56	5450
60	5400	19	5710	56	5468
60	5418	19	5729	56	5494
60	5436	19	5755	56	5520
60	5462	19	5773	56	5546
60	5481	43	5799	56	5564
60	5507	43	5818	56	5590
60	5533	43	5844	56	5609
60	5559	43	5862	56	5627
60	5577	43	5880	53	5653
60	5603	43	5899	53	5679
60	5622	43	5925	53	5698
31	5640	43	5943	53	5724
31	5658	43	5962	53	5742
31	5677	43	5980	53	5760
31	5695	43	5998	53	5779
31	5714	43	6024	53	5797
31	5732	35	6043	53	5816
31	5758	35	6061	53	5834
31	5776	35	6080	53	5860
31	5802	35	6098	48	5886
31	5821	35	6116	48	5904
31	5839	35	6135	48	5923
31	5865	35	6161	48	5941
18	5884	35	6179	48	5960
18	5902	35	6198	48	5978
18	5928	35	6216	48	5996
18	5954	35	6242	48	6015
18	5972	35	6260	48	6033
18	5998	35	6286	48	6059
18	6024	31	6312	48	6085
18	6050	31	6331	48	6111
18	6076	31	6357	49	6137
18	6102	31	6375	49	6156
18	6128	31	6394	49	6182
30	6154	31	6412	49	6200
30	6180	31	6430	49	6226
30	6199	31	6456	49	6244
30	6217	31	6482	49	6270
30	6236	31	6501	49	6296
30	6254	31	6527	49	6322
30	6272	52	6553	49	6348
30	6291	52	6579	49	6374
30	6309	52	6605	40	6393
30	6328	52	6631	40	6411
30	6346	52	6649	40	6437
30	6364	52	6668	40	6456
44	6390	52	6694	40	6482
44	6409	52	6720	40	6508
44	6427	52	6746	40	6534
44	6446	52	6764	40	6552
44	6464	52	6782	40	6570

44	6490	99	6801	40	6596
44	6508	99	6819	40	6622
44	6527	99	6838		
44	6553	99	6856		
44	6579	99	6874		
44	6605	99	6893		
44	6631	99	6919		
28	6649	99	6945		
28	6675	99	6971		
28	6701	99	6989		
28	6727	99	7008		
28	6753	99	7034		
28	6772	140	7060		
28	6790	140	7086		
28	6808	140	7104		
28	6827	140	7130		
28	6845	140	7148		
28	6864	140	7167		
20	6882	140	7185		
20	6900	140	7211		
20	6926	140	7230		
20	6945	140	7256		
20	6963	140	7274		
20	6982	122	7300		
20	7008	122	7326		
20	7026	122	7352		
20	7044	122	7370		
20	7070	122	7389		
20	7096	122	7407		
20	7122	122	7426		
		122	7444		
		122	7470		
		122	7496		
		122	7522		
		73	7548		
		73	7566		
		73	7585		
		73	7603		
		73	7622		
		73	7640		
		73	7658		
		73	7677		
		73	7695		
		73	7714		
		73	7740		
		73	7758		
		73	7776		
Main Ranges 7		**Main Ranges 8**		**Main Ranges 9**	
k_{sn} Values ($m^{0.9}$)	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**
424	92	35	81	164	225
424	110	35	107	164	251
424	129	35	133	164	277
424	147	35	152	164	303

424	166	35	178	164	329
424	184	35	196	164	348
424	202	35	214	164	374
424	221	35	233	164	400
424	239	35	251	164	426
424	258	35	277	164	444
424	284	35	303	164	462
424	302	35	329	164	481
424	320	35	348	164	499
424	339	35	366	164	518
424	357	35	392	164	544
424	376	35	410	164	570
424	394	35	436	164	596
424	412	35	455	164	614
424	431	35	473	164	640
424	449	35	492	164	658
424	468	35	510	164	684
424	486	35	528	164	710
424	504	35	547	200	736
424	523	35	565	200	762
424	541	35	584	200	788
424	560	51	610	200	814
424	578	51	628	200	840
511	596	51	646	200	866
511	615	51	665	200	892
511	633	51	683	200	918
511	652	51	702	200	944
511	670	51	720	200	970
511	688	51	746	234	996
511	707	51	772	234	1022
511	725	51	798	234	1048
511	744	51	824	234	1067
511	762	88	850	234	1085
511	780	88	876	234	1104
511	799	88	902	234	1122
511	817	88	928	234	1140
511	836	88	954	234	1159
464	854	88	980	234	1177
464	872	88	1006	234	1196
464	891	88	1032	234	1214
464	909	88	1058	256	1232
464	928	88	1084	256	1251
464	946	129	1110	256	1269
464	964	129	1136	256	1288
464	983	129	1162	256	1306
464	1001	129	1188	256	1324
464	1020	129	1214	256	1343
464	1038	129	1240	256	1361
464	1056	129	1266	256	1380
464	1075	129	1292	256	1398
464	1093	129	1318	256	1416
394	1112	207	1344	256	1435
394	1130	207	1370	256	1453
394	1148	207	1396	256	1472
394	1167	207	1422	305	1490
394	1185	207	1448	305	1508

394	1204	207	1474	305	1527
394	1222	207	1500	305	1545
394	1240	207	1526	305	1564
394	1259	207	1552	305	1582
394	1277	207	1578	305	1600
394	1296	233	1604	305	1619
394	1314	233	1630	305	1637
394	1332	233	1656	305	1656
456	1351	233	1682	305	1674
456	1377	233	1708	305	1692
456	1395	233	1734	305	1711
456	1414	233	1760	406	1729
456	1432	233	1778	406	1748
456	1450	233	1804	406	1766
456	1476	233	1830	406	1784
456	1502	232	1849	406	1803
456	1528	232	1875	406	1821
456	1554	232	1901	406	1840
456	1573	232	1927	406	1858
456	1591	232	1945	406	1876
494	1610	232	1971	406	1895
494	1628	232	1990	406	1913
494	1646	232	2008	406	1932
494	1665	232	2026	406	1950
494	1683	232	2045	406	1968
494	1702	232	2063	379	1987
494	1720	232	2082	379	2005
494	1738	233	2100	379	2024
494	1757	233	2118	379	2042
494	1775	233	2137	379	2060
494	1794	233	2155	379	2086
494	1812	233	2174	379	2105
494	1838	233	2192	379	2131
449	1864	233	2210	379	2149
449	1890	233	2229	379	2175
449	1916	233	2247	379	2194
449	1942	233	2266	379	2212
449	1960	233	2284	236	2230
449	1979	233	2310	236	2249
449	1997	233	2336	236	2267
449	2016	255	2362	236	2286
449	2034	255	2388	236	2304
449	2060	255	2406	236	2322
449	2086	255	2432	236	2348
385	2112	255	2458	236	2367
385	2138	255	2484	236	2385
385	2164	255	2510	236	2404
385	2182	255	2536	236	2422
385	2201	255	2562	236	2448
385	2219	300	2588	236	2474
385	2238	300	2607	154	2492
385	2256	300	2633	154	2511
385	2274	300	2659	154	2529
385	2293	300	2685	154	2548
385	2319	300	2711	154	2566
385	2337	300	2737	154	2584

327	2363	300	2755	154	2603
327	2389	300	2774	154	2621
327	2415	300	2792	154	2640
327	2441	300	2810	154	2658
327	2467	300	2829	154	2676
327	2486	328	2847	154	2695
327	2504	328	2873	154	2713
327	2522	328	2892	103	2732
327	2541	328	2910	103	2758
327	2559	328	2936	103	2776
327	2585	328	2962	103	2802
238	2611	328	2988	103	2820
238	2630	328	3014	103	2846
238	2648	328	3040	103	2865
238	2674	328	3058	103	2891
238	2692	328	3077	103	2917
238	2711	295	3095	103	2935
238	2729	295	3121	103	2961
238	2748	295	3147	58	2987
238	2774	295	3166	58	3013
238	2800	295	3184	58	3039
238	2818	295	3202	58	3065
238	2844	295	3221	58	3091
205	2870	295	3239	58	3117
205	2896	295	3265	58	3143
205	2914	295	3291	58	3169
205	2933	295	3317	58	3195
205	2951	163	3343	58	3221
205	2970	163	3369	50	3240
205	2988	163	3395	50	3266
205	3006	163	3421	50	3292
205	3025	163	3447	50	3318
205	3043	163	3466	50	3344
205	3062	163	3492	50	3362
205	3080	163	3518	50	3380
244	3098	163	3536	50	3399
244	3124	163	3554	50	3425
244	3150	163	3573	50	3443
244	3176	47	3591	50	3469
244	3195	47	3610	37	3495
244	3213	47	3628	37	3521
244	3232	47	3646	37	3547
244	3250	47	3665	37	3573
244	3268	47	3683	37	3592
244	3287	47	3702	37	3610
244	3305	47	3720	37	3628
244	3324	47	3738	37	3647
244	3342	47	3757	37	3665
197	3360	47	3775	37	3684
197	3379	47	3794	37	3702
197	3397	47	3820	37	3720
197	3416	55	3838	33	3739
197	3434	55	3856	33	3765
197	3452	55	3875	33	3791
197	3471	55	3893	33	3809
197	3489	55	3912	33	3828

197	3508	55	3930	33	3846
197	3534	55	3948	33	3872
197	3560	55	3967	33	3890
197	3586	55	3985	33	3909
81	3612	55	4004	33	3927
81	3638	55	4022	33	3946
81	3664	55	4040	33	3964
81	3682	55	4059	28	3982
81	3700	55	4085	28	4008
81	3719	66	4111	28	4034
81	3737	66	4137	28	4060
81	3756	66	4163	28	4079
81	3774	66	4189	28	4097
81	3792	66	4207	28	4116
81	3811	66	4226	28	4134
81	3829	66	4252	28	4160
76	3848	66	4270	28	4186
76	3866	66	4288	28	4204
76	3884	66	4314	28	4230
76	3910	80	4340	23	4256
76	3929	80	4359	23	4282
76	3955	80	4385	23	4301
76	3981	80	4411	23	4327
76	4007	80	4429	23	4353
76	4033	80	4448	23	4371
76	4059	80	4466	23	4397
76	4077	80	4484	23	4423
91	4096	80	4510	23	4442
91	4114	80	4536	23	4468
91	4132	80	4562		
91	4151	83	4588		
91	4169	83	4614		
91	4188	83	4633		
91	4206	83	4659		
91	4224	83	4677		
91	4243	83	4696		
91	4269	83	4722		
91	4287	83	4740		
91	4313	83	4766		
91	4339	83	4792		
85	4365	83	4818		
85	4391	70	4836		
85	4410	70	4855		
85	4436	70	4873		
85	4462	70	4892		
85	4488	70	4910		
85	4506	70	4928		
85	4524	70	4947		
85	4543	70	4965		
85	4569	70	4984		
85	4595	70	5002		
56	4613	70	5028		
56	4632	70	5054		
56	4658	70	5080		
56	4676	74	5106		
56	4702	74	5132		

56	4728	74	5150		
56	4746	74	5169		
56	4765	74	5195		
56	4783	74	5221		
56	4802	74	5239		
56	4820	74	5258		
56	4838	74	5276		
52	4857	74	5294		
52	4875	74	5313		
52	4894	74	5331		
52	4912	91	5350		
52	4930	91	5376		
52	4956	91	5394		
52	4982	91	5412		
52	5001	91	5431		
52	5027	91	5449		
52	5045	91	5468		
52	5064	91	5486		
52	5082	91	5504		
49	5100	91	5523		
49	5119	91	5541		
49	5137	91	5567		
49	5156	89	5586		
49	5174	89	5604		
49	5192	89	5622		
49	5211	89	5641		
49	5229	89	5659		
49	5248	89	5678		
49	5266	89	5696		
49	5284	89	5714		
49	5303	89	5733		
49	5321	89	5751		
49	5340	89	5770		
31	5358	89	5788		
31	5384	89	5806		
31	5410	89	5825		
31	5436				
31	5462				
31	5480				
31	5506				
31	5532				
31	5558				
31	5584				
Main Ranges 10		**Front Ranges 1**		**Front Ranges 2**	
k_{sn} Values ($m^{0.9}$)	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**
280	199	84	37	36	74
280	218	84	55	36	92
280	236	84	74	36	110
280	254	84	92	36	129
280	273	84	110	36	147
280	291	84	129	36	166
280	310	84	147	36	184
280	328	84	166	36	202

280	346	84	184	36	221
280	372	84	202	36	239
280	391	84	228	36	258
280	409	84	247	36	276
280	435	84	273	36	294
280	454	84	291	36	313
280	472	84	310	36	331
280	490	84	328	36	350
280	509	84	346	36	368
280	527	84	365	36	386
280	546	84	383	36	405
280	564	84	402	36	423
280	582	84	420	36	442
280	601	84	438	36	460
280	619	84	457	36	478
280	638	84	475	36	497
280	656	84	494	36	515
280	674	84	512	36	541
280	693	84	530	36	560
280	711	150	549	36	578
352	730	150	567	54	596
352	748	150	586	54	615
352	766	150	604	54	641
352	785	150	622	54	667
352	803	150	641	54	693
352	822	150	659	54	719
352	840	150	678	54	745
352	858	150	696	54	771
352	877	150	714	54	797
352	895	150	733	54	823
352	914	150	751	114	849
352	932	150	770	114	867
352	950	150	788	114	886
337	969	175	806	114	912
337	987	175	825	114	930
337	1006	175	843	114	948
337	1024	175	862	114	967
337	1042	175	880	114	985
337	1061	175	898	114	1011
337	1079	175	917	114	1030
337	1098	175	935	114	1048
337	1116	175	954	114	1066
337	1134	175	972	114	1085
337	1153	175	990	153	1103
337	1171	175	1009	153	1122
337	1190	175	1027	153	1140
337	1216	150	1046	153	1158
198	1234	150	1072	153	1177
198	1252	150	1098	153	1195
198	1271	150	1116	153	1221
198	1289	150	1134	153	1240
198	1308	150	1160	153	1266
198	1326	150	1179	153	1284
198	1344	150	1205	153	1310
198	1370	150	1223	153	1328
198	1389	150	1249	154	1354

198	1407	150	1275	154	1380
198	1426	150	1294	154	1399
198	1444	115	1312	154	1417
54	1470	115	1338	154	1443
54	1496	115	1364	154	1462
54	1514	115	1382	154	1480
54	1533	115	1408	154	1498
54	1551	115	1434	154	1517
54	1570	115	1460	154	1535
54	1596	115	1479	154	1554
54	1622	115	1505	154	1572
54	1648	115	1523	154	1590
54	1666	115	1549	138	1609
54	1684	94	1568	138	1627
54	1703	94	1586	138	1646
98	1729	94	1604	138	1664
98	1747	94	1623	138	1682
98	1766	94	1641	138	1701
98	1792	94	1660	138	1719
98	1818	94	1686	138	1738
98	1836	94	1704	138	1756
98	1854	94	1722	138	1774
98	1873	94	1741	138	1800
98	1891	94	1767	138	1819
98	1917	94	1785	138	1837
98	1936	72	1804	120	1856
98	1954	72	1822	120	1874
107	1972	72	1840	120	1892
107	1991	72	1859	120	1911
107	2009	72	1885	120	1929
107	2028	72	1911	120	1948
107	2046	72	1937	120	1966
107	2064	72	1955	120	1992
107	2083	72	1974	120	2010
107	2101	72	1992	120	2029
107	2120	72	2010	120	2047
107	2138	72	2036	120	2066
107	2164			120	2084
107	2190			118	2102
107	2216			118	2128
88	2242			118	2147
88	2260			118	2165
88	2279			118	2184
88	2297			118	2202
88	2316			118	2220
88	2334			118	2246
88	2360			118	2265
88	2378			118	2291
88	2404			118	2317
88	2430			118	2343
88	2449			152	2369
59	2467			152	2387
59	2493			152	2413
59	2519			152	2439
59	2538			152	2465
59	2564			152	2484

59	2582			152	2510
59	2608			152	2528
59	2634			152	2554
59	2652			152	2572
59	2671			146	2598
59	2689			146	2624
59	2708			146	2643
31	2734			146	2669
31	2752			146	2695
31	2778			146	2721
31	2804			146	2739
31	2830			146	2758
31	2856			146	2784
31	2874			146	2810
31	2893			146	2836
31	2911			98	2862
31	2937			98	2888
31	2956			98	2914
15	2974			98	2932
15	3000			98	2958
15	3026			98	2984
15	3052			98	3010
15	3078			98	3036
15	3104			98	3054
15	3130			98	3080
15	3148			58	3106
15	3167			58	3125
15	3193			58	3151
23	3219			58	3169
23	3237			58	3188
23	3256			58	3214
23	3274			58	3240
23	3292			58	3258
23	3311			58	3276
23	3329			58	3295
23	3348			58	3313
23	3366			58	3332
23	3384				
23	3403				
23	3421				
23	3440				
23	3458				
31	3484				
31	3510				
31	3536				
31	3562				
31	3588				
31	3606				
31	3625				
31	3651				
31	3669				
31	3688				
31	3706				
41	3724				
41	3743				
41	3761				

41	3780				
41	3806				
41	3832				
41	3850				
41	3876				
41	3902				
41	3920				
41	3939				
41	3957				
50	3983				
50	4002				
50	4028				
50	4046				
50	4064				
50	4090				
50	4109				
50	4127				
50	4153				
50	4179				
50	4198				
59	4216				
59	4234				
59	4253				
59	4279				
59	4305				
59	4331				
59	4357				
59	4383				
59	4401				
59	4420				
59	4438				
59	4456				
51	4475				
51	4501				
51	4519				
51	4538				
51	4556				
51	4574				
51	4593				
51	4611				
51	4630				
51	4648				
51	4666				
51	4685				
51	4703				
Front Ranges 3		**Front Ranges 4**		**Front Ranges 5**	
k_{sn} Values ($m^{0.9}$)	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**
131	81	146	208	55	55
131	100	146	234	55	81
131	118	146	260	55	100
131	136	146	286	55	118
131	155	146	312	55	136
131	173	146	338	55	155

131	192	146	364	55	173
131	210	146	390	55	199
131	228	146	416	55	225
131	247	146	442	55	244
131	265	146	468	55	262
131	291	146	494	55	280
131	310	146	520	55	306
131	328	146	546	55	332
131	346	146	564	55	351
131	365	146	590	55	369
131	391	146	616	55	395
131	417	146	642	55	421
131	443	146	668	55	447
131	461	146	687	55	466
131	487	146	705	55	484
131	506	146	731	55	502
131	532	174	757	55	528
131	558	174	783	55	554
131	584	174	809	104	573
193	610	174	828	104	599
193	636	174	846	104	617
193	662	174	872	104	636
193	688	174	890	104	662
193	714	174	909	104	688
193	740	174	927	104	706
193	766	174	946	104	724
193	792	174	964	104	743
193	818	179	982	104	769
193	844	179	1001	104	787
234	870	179	1019	104	806
234	896	179	1038	162	824
234	922	179	1064	162	842
234	940	179	1082	162	861
234	966	179	1100	162	879
234	992	179	1119	162	905
234	1018	179	1145	162	924
234	1044	179	1163	162	942
234	1062	179	1182	162	960
234	1088	179	1208	162	979
238	1114	179	1226	162	997
238	1133	176	1244	162	1023
238	1159	176	1270	162	1042
238	1177	176	1289	162	1060
238	1203	176	1315	186	1086
238	1229	176	1341	186	1104
238	1255	176	1367	186	1123
238	1274	176	1385	186	1149
238	1300	176	1411	186	1175
238	1318	176	1430	186	1193
238	1336	176	1456	186	1212
181	1362	176	1482	186	1230
181	1388	163	1508	186	1248
181	1407	163	1534	186	1267
181	1425	163	1560	186	1293
181	1444	163	1586	186	1311
181	1462	163	1612	205	1330

181	1480	163	1638	205	1348
181	1499	163	1664	205	1366
181	1525	163	1682	205	1385
181	1543	163	1708	205	1403
181	1562	139	1734	205	1422
181	1580	139	1760	205	1440
103	1606	139	1786	205	1458
103	1624	139	1804	205	1477
103	1650	139	1823	205	1495
103	1669	139	1849	205	1514
103	1687	139	1867	205	1532
103	1706	139	1886	205	1550
103	1732	139	1904	205	1569
103	1750	139	1922	138	1587
103	1768	139	1941	138	1606
103	1794	139	1959	138	1632
103	1813	96	1985	138	1650
103	1831	96	2011	138	1668
76	1857	96	2037	138	1687
76	1876	96	2063	138	1705
76	1894	96	2089	138	1731
76	1912	96	2108	138	1750
76	1931	96	2134	138	1776
76	1949	96	2160	138	1794
76	1975	96	2186	138	1812
76	1994	96	2204	50	1831
76	2012	96	2230	50	1857
76	2030	46	2256	50	1883
76	2049	46	2282	50	1909
76	2075	46	2308	50	1935
62	2101	46	2326	50	1953
62	2119	46	2345	50	1979
62	2138	46	2363	50	1998
62	2164	46	2382	50	2016
62	2182	46	2400	50	2042
62	2200	46	2426	50	2060
62	2226	46	2444	21	2086
62	2245	46	2463	21	2112
62	2263	41	2489	21	2138
62	2282	41	2507	21	2164
62	2300	41	2526	21	2190
62	2326	41	2544	21	2216
52	2344	41	2562	21	2242
52	2370	41	2581	21	2268
52	2389	41	2599	21	2294
52	2407	41	2618	21	2320
52	2426	41	2636	21	2346
52	2452	41	2654	21	2372
52	2478	41	2680	21	2398
52	2496	41	2699	21	2417
52	2514	41	2717	21	2443
52	2533	34	2736	21	2461
52	2551	34	2754	21	2480
52	2577	34	2772	21	2498
60	2596	34	2791	21	2524
60	2614	34	2817	21	2542

60	2632	34	2835	21	2561
60	2651	34	2861	13	2579
60	2669	34	2887	13	2598
60	2688	34	2913	13	2616
60	2714	34	2939	13	2634
60	2732	34	2965	13	2653
60	2758	20	2984	13	2671
60	2784	20	3002	13	2690
60	2802	20	3020	13	2716
60	2821	20	3039	13	2734
60	2839	20	3057	13	2752
60	2865	20	3076	13	2771
60	2884	20	3094	13	2797
60	2902	20	3112	13	2815
60	2928	20	3131	13	2834
60	2946	20	3149	13	2860
60	2972	20	3168	13	2878
60	2998	20	3194	13	2904
60	3017	20	3220	13	2922
60	3043			13	2941
60	3061			13	2959
60	3087			13	2978
51	3106			13	2996
51	3132			13	3014
51	3150			13	3033
51	3168			13	3051
51	3194			13	3070
51	3213			0	3096
51	3239			0	3122
51	3265			0	3140
51	3283			0	3158
51	3309			0	3184
51	3328			0	3210
68	3354			0	3229
68	3380			0	3247
68	3406			0	3266
68	3432			0	3284
68	3458			0	3302
68	3484			83	3321
68	3502			83	3339
68	3528			83	3358
68	3546			83	3376
68	3572			83	3394
68	3591			83	3413
77	3617			83	3431
77	3643			83	3450
77	3661			83	3468
77	3687			83	3486
77	3706			83	3512
77	3724			83	3531
77	3750			83	3549
77	3776			83	3575
77	3794			83	3601
77	3820			83	3620
66	3846			83	3646
66	3865			83	3664

66	3891			83	3682
66	3909			83	3708
66	3935			83	3727
66	3961			83	3745
66	3980			83	3764
66	3998			83	3782
66	4024			83	3800
66	4042			83	3819
66	4068			122	3837
66	4087			122	3856
52	4105			122	3874
52	4124			122	3892
52	4142			122	3911
52	4160			122	3929
52	4179			122	3948
52	4197			122	3966
52	4216			122	3984
52	4234			122	4003
52	4252			122	4021
52	4271			122	4040
52	4297			122	4058
52	4315			127	4076
52	4341			127	4095
45	4367			127	4113
45	4386			127	4132
45	4412			127	4150
45	4430			127	4168
45	4448			127	4187
45	4467			127	4205
45	4485			127	4224
45	4511			127	4242
45	4530			127	4268
45	4556			127	4286
45	4574			127	4305
42	4600			87	4331
42	4626			87	4349
42	4652			87	4368
42	4670			87	4386
42	4689			87	4404
42	4707			87	4423
42	4726			87	4441
42	4744			87	4460
42	4762			87	4486
42	4781			87	4504
42	4807			87	4530
42	4833			87	4556
				49	4582
				49	4608
				49	4634
				49	4652
				49	4678
				49	4704
				49	4723
				49	4749
				49	4775
				49	4793

				49	4819
				60	4845
				60	4864
				60	4882
				60	4900
				60	4919
				60	4945
				60	4971
				60	4989
				60	5008
				60	5026
				60	5044
				60	5063
				61	5089
				61	5107
				61	5133
				61	5159
				61	5178
				61	5196
				61	5222
				61	5240
				61	5266
				61	5285
				61	5303
				40	5329
				40	5355
				40	5381
				40	5407
				40	5426
				40	5444
				40	5462
				40	5481
				40	5499
				40	5518
				40	5536
				40	5562
Front Ranges 6		**Front Ranges 7**		**Front Ranges 8**	
k_{sn} Values ($m^{0.9}$)	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**
71	218	110	484	124	589
71	236	110	510	124	607
71	254	110	536	124	626
71	273	110	562	124	644
71	291	110	588	124	662
71	310	110	606	124	681
71	328	110	625	124	699
71	346	110	643	124	718
71	365	110	662	124	736
71	383	110	680	124	762
71	402	110	698	124	780
71	428	110	717	124	806
71	446	110	743	124	832
71	472	110	761	124	858
71	498	110	787	124	884

71	524	110	806	124	903
71	550	110	832	124	921
71	576	110	858	124	940
71	594	110	884	124	958
71	620	110	910	124	976
71	646	110	936	124	995
71	672	110	962	124	1021
71	698	110	988	124	1039
71	724	175	1014	124	1065
131	750	175	1040	124	1091
131	776	175	1066	189	1117
131	802	175	1092	189	1143
131	828	175	1118	189	1169
131	854	175	1144	189	1195
131	880	175	1170	189	1221
131	906	175	1196	189	1247
131	932	175	1222	189	1273
131	958	218	1248	189	1299
168	984	218	1274	189	1325
168	1010	218	1300	189	1351
168	1036	218	1326	213	1377
168	1055	218	1352	213	1403
168	1081	218	1378	213	1429
168	1099	218	1404	213	1455
168	1118	218	1430	213	1481
168	1136	218	1456	213	1507
168	1154	218	1482	213	1533
168	1173	211	1508	213	1559
168	1191	211	1534	213	1585
168	1210	211	1560	198	1611
179	1228	211	1586	198	1637
179	1246	211	1612	198	1663
179	1265	211	1638	198	1689
179	1283	211	1664	198	1715
179	1302	211	1690	198	1741
179	1320	211	1716	198	1767
179	1338	211	1742	198	1793
179	1357	172	1768	198	1819
179	1375	172	1794	198	1838
179	1394	172	1820	179	1864
179	1412	172	1846	179	1890
179	1430	172	1872	179	1916
179	1449	172	1890	179	1934
179	1467	172	1916	179	1952
185	1486	172	1934	179	1971
185	1512	172	1960	179	1989
185	1530	172	1986	179	2008
185	1548	138	2005	179	2026
185	1567	138	2023	179	2044
185	1585	138	2042	179	2063
185	1604	138	2060	179	2081
185	1622	138	2078	179	2100
185	1648	138	2097	126	2118
185	1666	138	2115	126	2136
185	1685	138	2134	126	2155
185	1703	138	2152	126	2173

185	1722	138	2178	126	2192
140	1748	138	2196	126	2210
140	1766	138	2215	126	2236
140	1784	138	2233	126	2262
140	1810	100	2252	126	2280
140	1829	100	2270	126	2299
140	1855	100	2288	126	2317
140	1881	100	2307	126	2336
140	1899	100	2325	67	2362
140	1918	100	2344	67	2380
140	1936	100	2362	67	2398
140	1954	100	2380	67	2417
140	1973	100	2399	67	2435
65	1991	100	2417	67	2454
65	2010	100	2436	67	2480
65	2028	100	2462	67	2498
65	2046	100	2488	67	2516
65	2065	67	2514	67	2535
65	2091	67	2540	67	2561
65	2109	67	2566	67	2579
65	2128	67	2584	67	2598
65	2146	67	2602	74	2616
65	2164	67	2621	74	2634
65	2190	67	2639	74	2653
65	2216	67	2665	74	2671
		67	2684	74	2690
		67	2702	74	2708
		67	2728	74	2734
		60	2746	74	2752
		60	2772	74	2771
		60	2791	74	2789
		60	2809	74	2808
		60	2828	74	2826
		60	2846	74	2844
		60	2872	86	2863
		60	2890	86	2881
		60	2916	86	2900
		60	2935	86	2918
		60	2953	86	2936
		60	2979	86	2962
		49	3005	86	2981
		49	3024	86	2999
		49	3042	86	3018
		49	3068	86	3036
		49	3086	86	3054
		49	3105	86	3080
		49	3131	86	3099
		49	3157	82	3117
		49	3175	82	3143
		49	3201	82	3162
		49	3220	82	3180
		49	3238	82	3206
		47	3256	82	3224
		47	3275	82	3243
		47	3293	82	3261
		47	3319	82	3280

		47	3338	82	3306
		47	3356	82	3324
		47	3382	82	3350
		47	3400	59	3368
		47	3426	59	3394
		47	3445	59	3413
		47	3471	59	3431
		40	3489	59	3450
		40	3508	59	3468
		40	3526	59	3486
		40	3552	59	3505
		40	3578	59	3523
		40	3596	59	3542
		40	3615	59	3560
		40	3633	59	3578
		40	3659	59	3597
		40	3678		
		40	3704		
		40	3730		
Front Ranges 9		**Front Ranges 10**		**Foothills 1**	
k_{sn} Values ($m^{0.9}$)	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**
55	26	210	133	36	115
55	52	210	159	36	141
55	78	210	185	36	159
55	104	210	204	36	185
55	130	210	230	36	211
55	156	210	248	36	237
55	182	210	274	36	263
55	208	210	292	36	289
55	234	210	311	36	308
55	260	210	329	36	334
55	286	210	348	36	360
55	312	210	366	36	386
55	338	210	384	36	404
55	364	210	403	36	430
55	382	210	429	36	456
55	408	210	447	36	482
55	427	210	466	36	508
55	453	210	484	36	534
55	479	210	502	36	552
55	505	210	521	36	578
55	531	210	539	36	604
85	557	210	558	36	630
85	583	210	584	29	649
85	609	210	602	29	675
85	635	210	620	29	701
85	661	210	639	29	719
85	687	266	665	29	738
85	713	266	691	29	764
85	739	266	709	29	790
85	765	266	735	29	808
85	791	266	761	29	834
106	817	266	780	29	852

106	843	266	798	29	878
106	869	266	816	30	904
106	895	266	842	30	923
106	921	266	861	30	941
106	939	266	879	30	967
106	965	231	898	30	993
106	991	231	916	30	1012
106	1017	231	934	30	1038
106	1043	231	953	30	1064
109	1069	231	971	30	1090
109	1095	231	990	30	1108
109	1121	231	1008	30	1134
109	1147	231	1026	30	1160
109	1166	231	1045	30	1178
109	1184	231	1071	30	1197
109	1202	231	1097	30	1223
109	1221	231	1123	30	1241
109	1239	231	1141	30	1260
109	1258	161	1167	30	1286
109	1276	161	1193	30	1304
100	1294	161	1219	30	1330
100	1313	161	1245	30	1348
100	1331	161	1271	30	1367
100	1357	161	1290	37	1385
100	1376	161	1316	37	1404
100	1394	161	1342	37	1422
100	1412	161	1368	37	1440
100	1431	161	1386	37	1459
100	1449	96	1404	37	1485
100	1468	96	1423	37	1503
100	1494	96	1441	37	1522
100	1520	96	1467	37	1540
101	1546	96	1486	37	1566
101	1572	96	1504	37	1584
101	1598	96	1522	37	1603
101	1624	96	1541	37	1621
101	1650	96	1559	37	1647
101	1676	96	1585	37	1666
101	1702	96	1604	37	1692
101	1728	96	1622	37	1710
101	1754	96	1640	37	1728
101	1772	84	1659	37	1747
96	1798	84	1685	37	1765
96	1824	84	1711	37	1791
96	1850	84	1729	37	1810
96	1876	84	1748	37	1828
96	1902	84	1774	37	1846
96	1928	84	1792	37	1872
96	1954	84	1818	36	1891
96	1980	84	1836	36	1917
96	2006	84	1855	36	1943
96	2032	84	1873	36	1969
84	2050	84	1892	36	1987
84	2076	105	1910	36	2006
84	2095	105	1928	36	2032
84	2121	105	1947	36	2058

84	2139	105	1965	36	2076
84	2165	105	1991	36	2102
84	2184	105	2010	36	2128
84	2210	105	2036	36	2146
84	2228	105	2054	36	2172
84	2246	105	2072	36	2198
84	2272	105	2098	36	2224
54	2298	105	2124	36	2243
54	2324	95	2150	36	2261
54	2350	95	2176	36	2280
54	2376	95	2202	36	2306
54	2402	95	2221	36	2332
54	2428	95	2247	36	2350
54	2454	95	2273	36	2368
54	2480	95	2299	33	2387
54	2506	95	2317	33	2413
54	2532	95	2343	33	2439
		95	2362	33	2457
		95	2380	33	2483
		74	2406	33	2502
		74	2424	33	2520
		74	2450	33	2538
		74	2476	33	2564
		74	2495	33	2590
		74	2521	33	2609
		74	2539	33	2627
		74	2565	24	2653
		74	2591	24	2679
		74	2610	24	2705
		74	2636	24	2724
		76	2654	24	2750
		76	2680	24	2768
		76	2698	24	2786
		76	2717	24	2805
		76	2735	24	2823
		76	2754	24	2842
		76	2772	24	2860
		76	2790	24	2878
		76	2809	18	2897
		76	2827	18	2923
		76	2846	18	2941
		76	2864	18	2960
		76	2890	18	2986
		78	2908	18	3004
		78	2927	18	3022
		78	2945	18	3041
		78	2971	18	3059
		78	2990	18	3085
		78	3008	18	3111
		78	3026	18	3130
		78	3045	28	3148
		78	3063	28	3174
		78	3082	28	3192
		78	3100	28	3211
		78	3126	28	3229
		51	3152	28	3248

		51	3170	28	3274
		51	3196	28	3292
		51	3222	28	3310
		51	3248	28	3336
		51	3274	28	3362
		51	3293	28	3388
		51	3319	28	3407
		51	3345	28	3433
		51	3371	28	3451
		51	3397	28	3477
		49	3415	28	3496
		49	3434	28	3522
		49	3460	28	3548
		49	3486	28	3574
		49	3504	28	3592
		49	3530	28	3610
		49	3556	32	3636
		49	3582	32	3655
		49	3600	32	3681
		49	3626	32	3707
		55	3645	32	3725
		55	3663	32	3744
		55	3682	32	3770
		55	3708	32	3788
		55	3734	32	3806
		55	3760	32	3825
		55	3786	32	3843
		55	3812	32	3862
		55	3830	44	3880
		55	3848	44	3898
		55	3867	44	3917
		55	3885	44	3935
				44	3954
				44	3972
				44	3990
				44	4009
				44	4027
				44	4046
				44	4064
				44	4090
				44	4116
				40	4142
				40	4168
				40	4194
				40	4220
				40	4246
				40	4272
				40	4290
				40	4309
				40	4335
				40	4353
				40	4372
				23	4398
				23	4416
				23	4442
				23	4460

				23	4486
				23	4505
				23	4531
				23	4557
				23	4575
				23	4601
				23	4620
				15	4646
				15	4672
				15	4698
				15	4716
				15	4742
				15	4760
				15	4779
				15	4805
				15	4823
				15	4849
				15	4875
				12	4894
				12	4920
				12	4946
				12	4972
				12	4990
				12	5008
				12	5034
				12	5060
				12	5079
				12	5105
				12	5131
				16	5157
				16	5183
				16	5201
				16	5227
				16	5246
				16	5272
				16	5298
				16	5324
				16	5342
				16	5360
				13	5386
				13	5412
				13	5438
				13	5464
				13	5483
				13	5509
				13	5527
				13	5553
				13	5579
				13	5605
				13	5624
				9	5642
				9	5660
				9	5686
				9	5705
				9	5723
				9	5742

				9	5760
				9	5778
				9	5797
				9	5815
				9	5834
				9	5852
				9	5870
Foothills 2		**Foothills 3**		**Foothills 4**	
k_{sn} Values ($m^{0.9}$)	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**
15	418	23	296	63	44
15	436	23	314	63	63
15	462	23	340	63	81
15	488	23	366	63	100
15	514	23	392	63	118
15	533	23	418	63	136
15	559	23	444	63	155
15	585	23	470	63	181
15	611	23	496	63	199
15	629	23	514	63	218
15	648	23	533	63	236
15	674	23	551	63	254
15	700	23	570	63	273
15	726	23	588	63	291
15	744	23	606	63	310
15	762	23	625	63	328
15	788	23	643	63	346
15	814	23	662	63	365
15	833	23	688	63	383
15	851	23	706	63	402
15	870	23	724	63	420
15	896	23	743	63	438
15	922	23	761	63	464
15	948	23	780	63	490
15	974	23	798	63	509
15	992	23	816	63	527
15	1018	23	835	63	546
15	1044	23	861	37	564
15	1070	23	887	37	590
15	1096	23	905	37	608
15	1122	23	924	37	634
15	1140	23	942	37	660
15	1166	23	968	37	686
15	1185	23	994	37	712
15	1203	23	1012	37	731
15	1222	23	1038	37	749
15	1240	23	1057	37	768
15	1258	23	1075	37	786
15	1277	23	1094	22	812
15	1295	23	1112	22	838
15	1314	23	1130	22	864
15	1332	23	1149	22	890
15	1350	23	1167	22	916
15	1369	23	1186	22	942

15	1387	23	1204	22	968
15	1406	23	1222	22	986
15	1432	23	1241	22	1005
15	1450	23	1259	22	1023
15	1468	23	1285	22	1042
15	1487	23	1311	37	1060
15	1505	23	1330	37	1078
15	1524	23	1348	37	1097
15	1550	23	1374	37	1115
15	1568	23	1400	37	1134
15	1586	23	1426	37	1152
15	1612	23	1444	37	1170
15	1631	23	1463	37	1189
15	1649	23	1489	37	1207
15	1668	23	1507	37	1226
15	1686	23	1526	37	1244
15	1704	23	1552	37	1270
15	1723	23	1578	37	1288
15	1741	23	1604	37	1307
15	1760	23	1622	37	1325
15	1778	23	1640	37	1344
15	1796	23	1659	37	1370
15	1815	23	1685	37	1396
15	1841	23	1703	37	1422
15	1859	23	1722	37	1440
15	1878	23	1740	37	1458
15	1896	23	1758	37	1477
15	1914	23	1784	37	1495
0	1933	32	1810	37	1514
0	1951	32	1829	37	1532
0	1970	32	1855	37	1558
0	1988	32	1873	37	1576
0	2014	32	1892	37	1595
0	2032	32	1910	37	1621
0	2058	32	1928	37	1639
0	2084	32	1947	37	1665
0	2103	32	1965	37	1684
0	2129	32	1984	37	1710
0	2147	32	2002	37	1736
30	2166	32	2028	37	1754
30	2184	32	2054	37	1772
30	2210	32	2080	37	1798
30	2228	32	2098	25	1824
30	2254	32	2117	25	1843
30	2273	32	2135	25	1869
30	2291	32	2154	25	1887
30	2317	32	2172	25	1913
30	2343	32	2190	25	1932
30	2362	32	2209	25	1958
30	2380	32	2227	25	1976
30	2406	32	2246	25	1994
30	2432	32	2264	25	2020
30	2450	32	2282	25	2046
30	2469	32	2301	25	2072
30	2487	32	2319	25	2098
30	2513	32	2338	25	2124

30	2539	32	2356	25	2143
30	2565	32	2374	25	2169
30	2584	32	2393	25	2187
30	2602	32	2411	25	2206
30	2628	32	2430	25	2232
30	2646	32	2448	25	2258
31	2672	32	2466	25	2284
31	2698	32	2485	15	2310
31	2724	32	2503	15	2336
31	2750	32	2529	15	2362
31	2776	32	2548	15	2388
31	2802	24	2566	15	2414
31	2828	24	2584	15	2432
31	2854	24	2610	15	2458
31	2880	24	2629	15	2484
31	2899	24	2647	15	2502
32	2925	24	2666	15	2521
32	2951	24	2684	15	2539
32	2977	24	2702	15	2565
32	2995	24	2721	15	2584
32	3021	24	2747	15	2610
32	3047	24	2765	15	2636
32	3066	24	2784	15	2654
32	3084	24	2802	15	2680
32	3110	24	2820	15	2706
32	3136	24	2839	15	2724
32	3162	24	2857	15	2750
32	3188	24	2876	15	2776
32	3206	24	2894	15	2802
32	3232	24	2912	0	2828
32	3251	24	2938	0	2847
32	3269	24	2957	0	2873
32	3295	24	2975	0	2899
32	3321	24	2994	0	2917
32	3347	24	3012	0	2936
32	3373	24	3030	0	2962
32	3399	24	3049	0	2980
25	3425	14	3067	0	3006
25	3451	14	3086	0	3032
25	3470	14	3104	37	3058
25	3496	14	3122	37	3076
25	3514	14	3141	37	3102
25	3532	14	3159	37	3128
25	3551	14	3178	37	3154
25	3569	14	3196	37	3180
25	3588	14	3214	37	3206
25	3606	14	3233	37	3232
25	3632	14	3251	37	3251
25	3650	14	3270	37	3277
20	3676	14	3288	37	3303
20	3695	14	3306	37	3329
20	3721	14	3325	37	3355
20	3739	14	3343	37	3373
20	3758	14	3362	37	3399
20	3776	14	3380	37	3425
20	3802	14	3398	37	3451

20	3828	14	3417	37	3470
20	3846	14	3435	37	3496
20	3872	14	3454	37	3522
20	3898	14	3472	37	3540
17	3924	14	3490	43	3566
17	3943	14	3509	43	3584
17	3969	14	3527	43	3603
17	3987	14	3546	43	3621
17	4006	14	3564	43	3640
17	4024	14	3582	43	3658
17	4050	14	3601	43	3676
17	4076	14	3619	43	3695
17	4094	14	3638	43	3721
17	4113	14	3656	43	3739
17	4131	14	3674	43	3765
17	4150	14	3693	43	3791
18	4168	14	3711	46	3817
18	4186	14	3730	46	3843
18	4212	14	3748	46	3869
18	4231	14	3766	46	3895
18	4257	14	3785	46	3921
18	4275	14	3803	46	3940
18	4294	0	3822	46	3958
18	4320	0	3840	46	3984
18	4346	0	3858	46	4002
18	4372	0	3877	46	4021
18	4398	0	3895	46	4039
18	4424	0	3914	47	4065
18	4442	0	3932	47	4084
18	4468	0	3950	47	4102
18	4494	0	3969	47	4120
18	4520	0	3987	47	4139
18	4538	0	4006	47	4157
18	4564	0	4024	47	4183
18	4590	0	4042	47	4202
18	4609	0	4068	47	4228
18	4627	0	4087	47	4254
18	4646	0	4105	47	4280
18	4664	0	4131	47	4298
12	4682	0	4157	29	4324
12	4708	0	4176	29	4350
12	4727	0	4194	29	4376
12	4745	0	4220	29	4402
12	4764	0	4238	29	4420
12	4782	0	4257	29	4446
12	4800	0	4275	29	4472
12	4819	14	4301	29	4498
12	4837	14	4320	29	4517
12	4856	14	4338	29	4543
12	4874	14	4364	17	4569
12	4900	14	4390	17	4587
8	4926	14	4416	17	4606
8	4944	14	4442	17	4632
8	4963	14	4460	17	4650
8	4981	14	4479	17	4668
8	5007	14	4497	17	4694

8	5026	14	4516	17	4720
8	5044	14	4542	17	4746
8	5070	14	4568	17	4772
8	5088	14	4594	17	4798
8	5107	14	4612	28	4824
8	5125	14	4630	28	4850
8	5144	14	4649	28	4876
8	5162	14	4667	28	4895
0	5180	14	4686	28	4921
0	5199	14	4704	28	4947
0	5225	14	4722	28	4965
0	5251	14	4741	28	4984
0	5269	14	4759	28	5002
0	5288	14	4778	28	5020
0	5306	14	4796	28	5039
0	5324	14	4814	28	5065
0	5350	14	4833	28	5083
0	5369	14	4851	28	5102
0	5387	14	4870	28	5128
14	5406	14	4896	28	5146
14	5432	14	4914	28	5164
14	5450	14	4932	28	5183
14	5476	14	4958	28	5209
14	5494	14	4984	28	5235
14	5520	14	5010	28	5253
14	5546	14	5036	28	5272
14	5572	0	5062	28	5290
14	5591	0	5088	25	5308
14	5609	0	5114	25	5327
14	5635	0	5140	25	5353
14	5661	0	5159	25	5379
14	5680	0	5177	25	5397
14	5698	0	5196	25	5416
14	5724	0	5222	25	5442
14	5742	0	5248	25	5468
14	5768	0	5274	25	5494
14	5787	10	5300	25	5520
14	5805	10	5318	25	5546
14	5824	10	5336	16	5572
14	5850	10	5355	16	5590
14	5868	10	5373	16	5616
14	5886	10	5392	16	5634
14	5905	10	5410	16	5660
11	5923	10	5428	16	5686
11	5942	10	5447	16	5705
11	5960	10	5465	16	5731
11	5978	10	5484	16	5749
11	6004	10	5502	16	5775
11	6023	10	5520	16	5801
11	6041	10	5539	11	5827
11	6060	10	5557	11	5853
11	6078	10	5576	11	5879
11	6096	10	5594	11	5905
11	6122	10	5612	11	5931
11	6148	10	5631	11	5957
7	6174	10	5657	11	5983

7	6193	10	5683	11	6002
7	6219	10	5701	11	6028
7	6237	10	5727	11	6054
7	6256	10	5753	11	6080
7	6282	10	5772	11	6098
7	6308	10	5798	11	6116
7	6326	10	5824	11	6142
7	6344	10	5842	11	6168
7	6363	10	5860	11	6187
7	6381	10	5879	11	6205
7	6407	10	5897	11	6231
		10	5916	11	6250
		10	5934	11	6276
		10	5960	11	6294
		10	5986	11	6320
		10	6012	11	6346
		10	6038	11	6372
		0	6064	11	6398
		0	6090	11	6416
		0	6116	11	6442
		0	6134	11	6468
		0	6153	11	6487
		0	6179	11	6505
		0	6197	11	6531
		0	6216	11	6550
		0	6234	18	6576
		0	6252	18	6594
		0	6271	18	6620
		0	6297	18	6646
		0	6323	18	6672
		0	6341	18	6690
		0	6360	18	6709
		0	6378	18	6735
		0	6396	18	6753
		0	6415	18	6772
		0	6433	18	6790
		0	6452	18	6808
		0	6470	18	6834
		0	6488	18	6860
		0	6507	18	6879
		0	6525	18	6897
		0	6544	18	6916
		0	6562	18	6934
		0	6580	18	6952
		0	6606	18	6971
		0	6632	18	6989
		0	6651	18	7008
		0	6669	18	7026
		0	6695	18	7044
		0	6721	17	7063
		0	6747	17	7089
		0	6773	17	7107
		16	6799	17	7126
		16	6818	17	7152
		16	6836	17	7170
		16	6854	17	7188

		16	6880	17	7207
		16	6899	17	7225
		16	6917	17	7244
		16	6943	17	7262
		16	6969	17	7280
		16	6995	17	7299
		16	7014	9	7317
		16	7032	9	7336
		16	7058	9	7354
		16	7084	9	7372
		16	7110	9	7391
		16	7136	9	7409
		16	7154	9	7428
		16	7173	9	7446
		16	7191	9	7464
		16	7210	9	7483
		16	7228	9	7501
		16	7246	9	7520
		16	7265	9	7546
		16	7283		
		16	7302		
		16	7320		
		16	7338		
		16	7357		
		16	7375		
		16	7394		
		16	7420		
		16	7446		
		16	7464		
		16	7482		
		16	7501		
		16	7519		
		16	7538		
		10	7556		
		10	7574		
		10	7600		
		10	7626		
		10	7645		
		10	7663		
		10	7682		
		10	7708		
		10	7726		
		10	7744		
		10	7763		
		10	7781		
		10	7800		
		10	7818		
		10	7836		
		10	7855		
		10	7873		
		10	7892		
		10	7910		
		10	7928		
		10	7947		
		10	7965		
		10	7984		

		10 10 10 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 10 10 10 10 10 10 10 10 10 10 10 10 10 10 11 11 11 11 11	8002 8020 8039 8057 8083 8109 8135 8161 8187 8213 8232 8258 8276 8294 8320 8346 8372 8398 8424 8443 8461 8480 8498 8516 8542 8561 8587 8613 8631 8650 8676 8694 8712 8738 8757 8775 8794 8812 8830 8849 8867 8886 8904 8922 8941 8959 8978 8996 9014 9033 9051 9070 9088 9114 9140 9158		

		11	9184		
		11	9203		
		11	9229		
		11	9255		
		11	9281		
		11	9307		
		8	9333		
		8	9359		
		8	9385		
		8	9403		
		8	9429		
		8	9455		
		8	9481		
		8	9507		
		8	9533		
		8	9559		
		4	9578		
		4	9596		
		4	9614		
		4	9640		
		4	9659		
		4	9677		
		4	9696		
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		4	9788		
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		3	9832		
		3	9850		
		3	9869		
		3	9895		
		3	9921		
		3	9947		
		3	9965		
		3	9991		
		3	10010		
		3	10028		
		3	10046		
Foothills 5		**Foothills 6**		**Foothills 7**	
k_{sn} Values ($m^{0.9}$)	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**
20	115	41	467	33	498
20	141	41	485	33	516
20	159	41	504	33	542
20	185	41	522	33	568
20	211	41	540	33	594
20	230	41	559	33	620
20	248	41	577	33	639
20	266	41	596	33	657
20	292	41	614	33	676
20	318	41	640	33	694

20	337	41	666	33	720
20	355	41	684	33	738
20	374	41	710	33	764
20	392	41	729	33	790
20	410	41	755	33	816
20	429	41	773	33	842
20	447	41	792	33	868
20	466	41	810	33	894
20	484	41	828	33	920
20	510	41	847	33	939
20	536	41	865	33	957
20	562	41	884	33	976
20	588	41	902	33	1002
20	614	41	920	33	1028
22	640	41	939	33	1054
22	658	41	957	33	1080
22	677	41	976	33	1098
22	695	41	994	33	1116
22	714	41	1012	33	1135
22	732	41	1031	33	1153
22	750	41	1049	33	1172
22	769	41	1068	33	1198
22	787	41	1086	33	1224
22	806	41	1104	33	1250
22	824	41	1123	31	1268
22	842	41	1141	31	1294
22	861	41	1160	31	1320
22	879	41	1178	31	1346
22	898	41	1196	31	1372
22	916	41	1215	31	1398
22	934	45	1233	31	1416
22	953	45	1252	31	1435
22	971	45	1278	31	1453
22	990	45	1304	31	1472
22	1008	45	1330	31	1490
22	1026	45	1348	31	1508
22	1045	45	1374	31	1527
22	1063	45	1392	31	1545
22	1082	45	1411	31	1564
22	1100	45	1429	31	1582
22	1118	45	1455	31	1600
22	1144	45	1474	31	1619
22	1163	41	1492	31	1637
22	1189	41	1518	31	1663
22	1207	41	1544	31	1689
22	1233	41	1562	31	1715
22	1252	41	1581	31	1741
22	1270	41	1607	47	1760
22	1288	41	1633	47	1778
22	1307	41	1651	47	1796
22	1325	41	1677	47	1815
22	1344	41	1703	47	1841
22	1362	41	1722	47	1867
21	1380	37	1740	47	1893
21	1399	37	1766	47	1911
21	1425	37	1792	47	1937

21	1443	37	1818	47	1956
21	1469	37	1844	47	1974
21	1488	37	1870	47	1992
21	1506	37	1888	47	2011
21	1532	37	1907	47	2029
21	1558	37	1925	47	2055
21	1584	37	1951	47	2074
21	1610	37	1970	47	2092
21	1636	31	1988	47	2118
21	1654	31	2006	47	2136
21	1680	31	2025	47	2162
21	1706	31	2051	47	2188
21	1725	31	2077	47	2207
21	1751	31	2095	47	2225
21	1769	31	2121	47	2244
21	1788	31	2147	38	2262
21	1814	31	2173	38	2280
21	1840	31	2199	38	2299
21	1866	31	2225	38	2317
21	1892	31	2244	38	2336
21	1918	31	2262	38	2354
21	1936	31	2280	38	2372
21	1962	31	2306	38	2398
21	1988	31	2325	38	2417
21	2014	31	2351	38	2435
21	2032	31	2377	38	2454
21	2058	31	2395	38	2480
21	2084	31	2421	38	2506
21	2110	31	2447	31	2532
20	2136	31	2473	31	2550
20	2162	29	2492	31	2576
20	2181	29	2510	31	2594
20	2207	29	2536	31	2613
20	2225	29	2562	31	2631
20	2251	29	2588	31	2650
20	2270	29	2614	31	2668
20	2296	29	2632	31	2686
20	2314	29	2658	31	2705
20	2340	29	2684	31	2723
20	2366	29	2710	31	2742
20	2392	29	2729	29	2760
20	2418	29	2755	29	2778
20	2436	29	2773	29	2797
20	2462	29	2792	29	2815
20	2488	29	2810	29	2834
20	2507	29	2828	29	2860
20	2533	29	2847	29	2878
20	2551	29	2865	29	2904
20	2570	29	2891	29	2930
20	2588	29	2917	29	2948
20	2614	29	2936	29	2974
29	2640	29	2962	29	2993
29	2666	49	2988	29	3011
29	2692	49	3014	29	3037
29	2710	49	3040	29	3063
29	2736	49	3058	29	3089

29	2762	49	3084	29	3108
29	2781	49	3102	29	3126
29	2807	49	3128	29	3144
29	2825	49	3147	29	3163
29	2844	49	3173	29	3181
29	2870	49	3199	29	3200
29	2896	49	3225	29	3218
29	2914	49	3251	29	3236
29	2932	49	3269	29	3255
29	2951	49	3295	29	3273
29	2977	49	3314	29	3292
29	2995	49	3340	29	3310
29	3021	49	3366	29	3328
29	3047	49	3392	29	3347
29	3073	49	3418	29	3365
29	3099	49	3444	29	3384
34	3125	49	3462	29	3402
34	3144	63	3480	29	3420
34	3162	63	3499	29	3439
34	3180	63	3517	29	3457
34	3199	63	3536	29	3483
34	3217	63	3554	29	3502
34	3236	63	3580	51	3520
34	3254	63	3606	51	3538
34	3272	63	3624	51	3557
34	3291	63	3650	51	3575
34	3309	63	3676	51	3594
34	3335	63	3702	51	3612
34	3354	63	3721	51	3630
50	3372	57	3739	51	3649
50	3398	57	3758	51	3675
50	3424	57	3784	51	3693
50	3450	57	3810	51	3719
50	3468	57	3836	51	3738
50	3487	57	3862	63	3764
50	3505	57	3880	63	3790
50	3531	57	3906	63	3808
50	3550	57	3932	63	3826
50	3568	57	3958	63	3845
50	3586	57	3976	63	3871
50	3612	41	4002	63	3889
46	3638	41	4028	63	3915
46	3657	41	4047	63	3941
46	3675	41	4065	63	3960
46	3694	41	4084	63	3986
46	3720	41	4102	46	4012
46	3738	41	4120	46	4038
46	3764	41	4139	46	4064
46	3782	41	4165	46	4090
46	3808	41	4183	46	4108
46	3834	41	4202	46	4134
46	3853	41	4220	46	4160
31	3871	29	4238	46	4186
31	3890	29	4257	46	4212
31	3908	29	4283	46	4238
31	3926	29	4301	19	4264

31	3945	29	4320	19	4290
31	3963	29	4338	19	4316
31	3982	29	4356	19	4342
31	4000	29	4375	19	4368
31	4026	29	4393	19	4394
31	4044	29	4412	19	4412
31	4063	29	4430	19	4431
31	4081	29	4448	19	4457
31	4100	29	4467	19	4483
9	4118	26	4485	19	4509
9	4144	26	4504	29	4535
9	4170	26	4530	29	4561
9	4188	26	4548	29	4587
9	4207	26	4566	29	4613
9	4225	26	4585	29	4639
9	4244	26	4603	29	4665
9	4262	26	4629	29	4691
9	4280	26	4648	29	4709
9	4306	26	4666	29	4728
9	4332	26	4684	29	4746
9	4358	26	4710	29	4764
3	4384	32	4736	29	4783
3	4403	32	4762	29	4801
3	4421	32	4781	29	4820
3	4447	32	4799	29	4846
3	4473	32	4818	29	4864
3	4499	32	4844	29	4882
3	4525	32	4862	29	4901
3	4551	32	4888	29	4927
3	4577	32	4914	29	4945
3	4603	32	4940	29	4964
0	4629	32	4958	29	4982
0	4655	32	4977	29	5000
0	4681	42	5003	34	5019
0	4707	42	5021	34	5045
0	4733	42	5047	34	5063
0	4759	42	5073	34	5082
0	4785	42	5092	34	5100
0	4811	42	5118	34	5118
0	4837	42	5144	34	5137
0	4863	42	5162	34	5163
0	4889	42	5180	34	5189
0	4908	42	5199	34	5215
0	4934	42	5217	34	5241
0	4952	44	5236	42	5267
0	4978	44	5254	42	5285
0	4996	44	5272	42	5304
0	5022	44	5298	42	5322
0	5048	44	5317	42	5340
0	5067	44	5335	42	5359
0	5085	44	5354	42	5385
0	5104	44	5372	42	5411
0	5122	44	5390	42	5437
0	5140	44	5409	42	5455
0	5159	44	5427	42	5481
0	5177	44	5446	42	5507

0	5196	44	5464	45	5526
0	5214	36	5482	45	5544
0	5232	36	5501	45	5562
0	5251	36	5519	45	5581
0	5277	36	5545	45	5599
0	5303	36	5571	45	5625
0	5321	36	5590	45	5644
0	5340	36	5608	45	5662
1	5366	36	5626	45	5680
1	5392	36	5652	45	5699
1	5410	36	5671	45	5717
1	5436	36	5689	45	5736
1	5462	36	5708	45	5754
1	5488	36	5734	46	5772
1	5506	36	5752	46	5791
1	5525	36	5778	46	5809
1	5543	36	5804	46	5835
1	5562	36	5822	46	5854
1	5580	36	5841	46	5872
1	5598	36	5859	46	5890
1	5617	36	5878	46	5909
1	5635	36	5896	46	5927
1	5654	36	5914	46	5946
1	5672	36	5933	46	5964
1	5690	36	5959	46	5990
1	5709	36	5977	42	6008
1	5735	28	6003	42	6027
1	5761	28	6022	42	6045
1	5787	28	6040	42	6064
1	5805	28	6058	42	6082
1	5831	28	6084	42	6100
1	5857	28	6110	42	6119
		28	6129	42	6145
		28	6155	42	6163
		28	6181	42	6182
		28	6207	42	6200
		28	6225	42	6226
		22	6244	42	6244
		22	6262	32	6263
		22	6280	32	6281
		22	6299	32	6300
		22	6317	32	6326
		22	6336	32	6352
		22	6354	32	6378
		22	6372	32	6396
		22	6391	32	6414
		22	6409	32	6433
		22	6428	32	6451
		22	6446	32	6470
		22	6464	32	6496
		29	6483	31	6514
		29	6509	31	6532
		29	6527	31	6551
		29	6546	31	6569
		29	6564	31	6588
		29	6582	31	6606

		29	6601	31	6624
		29	6619	31	6643
		29	6638	31	6661
		29	6656	31	6687
		29	6674	31	6706
		29	6693	31	6724
		29	6711	31	6742
		30	6730	25	6761
		30	6748	25	6779
		30	6766	25	6798
		30	6785	25	6816
		30	6803	25	6834
		30	6829	25	6853
		30	6848	25	6871
		30	6874	25	6890
		30	6900	25	6908
		30	6926	25	6926
		30	6952	25	6945
		30	6970	25	6971
		21	6988	25	6989
		21	7007	16	7008
		21	7025	16	7026
		21	7044	16	7044
		21	7070	16	7063
		21	7088	16	7081
		21	7114	16	7100
		21	7132	16	7118
		21	7151	16	7136
		21	7177	16	7155
		21	7203	16	7173
		21	7229	16	7192
		10	7247	16	7210
		10	7273	16	7228
		10	7299	16	7247
		10	7318	9	7265
		10	7336	9	7284
		10	7362	9	7302
		10	7388	9	7328
		10	7414	9	7346
		10	7440	9	7365
		10	7466	9	7391
		14	7492	9	7409
		14	7518	9	7428
		14	7544	9	7446
		14	7562	9	7472
		14	7588	9	7498
		14	7614		
		14	7633		
		14	7659		
		14	7677		
		14	7696		
		14	7714		
		13	7740		
		13	7758		
		13	7784		
		13	7803		

		13	7821		
		13	7840		
		13	7858		
		13	7876		
		13	7902		
		13	7921		
		13	7939		
		13	7958		
		13	7976		
		15	7994		
		15	8013		
		15	8039		
		15	8065		
		15	8083		
		15	8102		
		15	8120		
		15	8138		
		15	8157		
		15	8175		
		15	8194		
		15	8212		
		17	8230		
		17	8249		
		17	8267		
		17	8286		
		17	8304		
		17	8322		
		17	8341		
		17	8359		
		17	8378		
		17	8396		
		17	8414		
		17	8433		
		17	8451		
		17	8470		
Foothills 8		**Foothills 9**		**Foothills 10**	
k_{sn} Values ($m^{0.9}$)	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**	**k_{sn} Values ($m^{0.9}$)**	**Upstream Distance (m)**
20	717	20	466	30	440
20	735	20	484	30	458
20	754	20	502	30	484
20	772	20	521	30	510
20	790	20	547	30	536
20	809	20	573	30	554
20	835	20	591	30	573
20	861	20	610	30	591
20	887	20	628	30	610
20	905	20	646	30	628
20	924	20	665	30	646
20	950	20	683	30	665
20	968	20	702	30	683
20	986	20	720	30	702
20	1012	20	738	30	720
20	1031	20	757	30	738

20	1049	20	783	30	757
20	1075	20	809	30	775
20	1101	20	835	30	794
20	1120	20	861	30	812
20	1146	20	879	30	830
20	1172	20	905	30	849
20	1198	20	931	30	867
20	1224	20	957	30	886
20	1242	20	983	30	904
20	1268	20	1009	30	922
20	1294	20	1035	30	941
20	1320	20	1054	30	959
20	1346	20	1072	30	978
20	1372	20	1090	30	996
20	1398	20	1109	30	1014
20	1416	20	1135	30	1033
20	1435	20	1161	30	1051
20	1453	20	1179	30	1077
20	1472	20	1205	30	1103
0	1498	20	1224	30	1122
0	1516	0	1250	30	1148
0	1534	0	1276	30	1166
0	1553	0	1302	30	1192
0	1571	0	1320	17	1210
0	1590	0	1338	17	1236
0	1608	0	1357	17	1262
0	1626	0	1383	17	1288
0	1652	0	1401	17	1307
0	1678	0	1427	17	1333
0	1697	0	1446	17	1351
21	1715	0	1472	17	1370
21	1734	0	1490	17	1388
21	1760	0	1508	17	1406
21	1778	0	1534	17	1432
21	1796	0	1553	17	1451
21	1822	0	1571	17	1477
21	1841	0	1590	17	1503
21	1867	0	1608	17	1521
21	1893	0	1626	17	1547
21	1911	0	1652	17	1566
21	1930	0	1678	17	1584
21	1948	0	1704	17	1610
21	1974	48	1730	17	1628
21	1992	48	1756	17	1647
21	2011	48	1782	17	1665
21	2037	48	1808	17	1684
21	2055	48	1834	17	1710
21	2081	48	1853	17	1728
21	2107	48	1871	17	1754
21	2133	48	1890	17	1780
21	2159	48	1908	17	1798
21	2185	48	1934	17	1817
21	2211	48	1960	17	1843
21	2237	48	1986	17	1861
21	2256	48	2012	17	1887
21	2274	48	2038	17	1906

21	2292	48	2056	17	1924
21	2311	48	2075	0	1950
21	2329	48	2093	0	1976
21	2348	48	2112	0	2002
21	2374	48	2130	0	2020
21	2400	48	2148	0	2046
21	2426	48	2167	0	2065
21	2452	48	2185	0	2083
31	2478	48	2211	0	2102
31	2496	45	2230	0	2120
31	2514	45	2248	0	2138
31	2533	45	2274	0	2157
31	2551	45	2292	0	2183
31	2570	45	2318	0	2209
31	2588	45	2344	0	2235
31	2614	45	2363	0	2261
31	2640	45	2381	0	2287
31	2666	45	2407	0	2313
31	2684	45	2433	0	2339
31	2703	45	2452	0	2357
31	2729	45	2478	0	2383
31	2747	42	2496	0	2402
31	2773	42	2514	0	2428
31	2792	42	2533	0	2454
31	2818	42	2551	0	2480
31	2836	42	2570	0	2506
31	2854	42	2588	0	2532
31	2880	42	2606	0	2550
31	2899	42	2625	0	2576
31	2917	42	2643	0	2594
31	2943	42	2669	0	2613
31	2962	42	2688	0	2631
31	2988	42	2706	0	2657
31	3014	42	2724	25	2683
31	3032	21	2743	25	2709
31	3050	21	2769	25	2735
31	3069	21	2787	25	2761
31	3095	21	2813	25	2787
31	3113	21	2839	25	2813
31	3139	21	2858	25	2832
31	3158	21	2876	25	2850
31	3184	21	2894	25	2868
31	3202	21	2920	25	2887
31	3228	21	2946	25	2905
31	3246	21	2965	25	2924
31	3265	21	2983	25	2950
31	3291	21	3002	25	2968
31	3309	21	3020	25	2986
31	3328	21	3038	25	3005
31	3354	21	3057	25	3023
31	3372	21	3083	25	3042
31	3390	21	3101	25	3068
31	3409	21	3120	25	3094
31	3427	21	3138	25	3120
31	3446	21	3156	25	3138
31	3464	21	3175	25	3164

31	3482	21	3193	25	3182
31	3501	21	3212	25	3208
31	3519	27	3230	25	3227
31	3538	27	3248	25	3253
31	3556	27	3267	25	3279
31	3574	27	3285	25	3305
31	3593	27	3304	25	3331
31	3619	27	3322	25	3357
31	3637	27	3340	25	3375
31	3663	27	3359	25	3394
31	3689	27	3377	25	3420
31	3708	27	3396	25	3438
31	3726	27	3414	0	3464
31	3752	27	3432	0	3490
31	3778	27	3451	0	3508
31	3804	27	3469	0	3534
31	3830	27	3495	0	3560
31	3856	27	3514	0	3579
31	3874	27	3532	0	3597
31	3893	27	3550	0	3623
31	3919	27	3569	0	3649
31	3937	27	3587	0	3668
31	3963	27	3606	34	3694
35	3989	27	3624	34	3720
35	4015	27	3642	34	3746
35	4034	27	3668	34	3764
35	4052	27	3687	34	3790
35	4070	27	3705	34	3808
35	4089	27	3731	34	3834
35	4115	27	3757	34	3860
35	4133	27	3776	34	3879
35	4152	27	3794	34	3905
35	4178	27	3820	34	3923
35	4196	27	3838	34	3949
35	4222	27	3857	34	3968
35	4248	27	3875	34	3986
35	4266	27	3894	34	4004
35	4285	27	3912	34	4023
35	4303	27	3930	34	4049
35	4329	27	3949	34	4067
35	4355	27	3967	34	4086
35	4374	26	3986	34	4112
35	4392	26	4004	34	4130
35	4418	26	4022	34	4156
35	4444	26	4041	34	4174
35	4470	26	4059	34	4193
50	4488	26	4078	34	4219
50	4507	26	4104	34	4237
50	4525	26	4122	34	4263
50	4544	26	4140	34	4282
50	4562	26	4159	34	4308
50	4580	26	4185	34	4334
50	4599	26	4203	34	4352
50	4617	26	4229	34	4378
50	4643	34	4255	34	4396
50	4669	34	4274	34	4422

50	4695	34	4292	57	4448
50	4721	34	4310	57	4474
37	4740	34	4329	57	4500
37	4758	34	4347	57	4526
37	4784	34	4366	57	4545
37	4802	34	4384	57	4563
37	4828	34	4402	57	4589
37	4854	34	4421	57	4615
37	4873	34	4439	57	4634
37	4899	34	4458	57	4660
37	4917	34	4476	57	4686
37	4936	43	4494	57	4712
37	4962	43	4513	57	4738
28	4980	43	4531	57	4764
28	5006	43	4550	57	4790
28	5032	43	4568	57	4808
28	5058	43	4586	57	4834
28	5084	43	4605	57	4860
28	5102	43	4623	57	4886
28	5121	43	4642	57	4904
28	5139	43	4660	57	4930
28	5158	43	4678	57	4949
28	5176	43	4697	57	4975
28	5194	43	4715	57	5001
28	5213	45	4734	57	5027
22	5231	45	4752	57	5053
22	5250	45	4770	57	5071
22	5268	45	4789	57	5097
22	5286	45	4807	57	5116
22	5305	45	4826	57	5134
22	5323	45	4844	57	5152
22	5342	45	4862	57	5171
22	5360	45	4881	57	5189
22	5378	45	4899	38	5208
22	5397	45	4918	38	5226
22	5415	45	4936	38	5244
22	5434	45	4954	38	5263
22	5452	45	4973	38	5281
22	5470	49	4999	38	5300
22	5489	49	5017	38	5318
22	5507	49	5036	38	5336
22	5533	49	5054	38	5355
22	5559	49	5072	38	5373
22	5578	49	5091	38	5392
22	5604	49	5109	38	5410
22	5630	49	5128	38	5428
22	5656	49	5154	38	5447
22	5682	49	5172	38	5465
22	5700	49	5190	38	5484
22	5726	49	5209	38	5502
22	5752	49	5227	38	5520
22	5770	65	5246	38	5539
22	5789	65	5264	38	5557
22	5807	65	5282	38	5576
22	5826	65	5301	38	5602
22	5844	65	5319	38	5628

22	5870	65	5338	38	5646
22	5896	65	5356	38	5664
22	5914	65	5374	38	5683
22	5933	65	5393	41	5701
22	5951	65	5411	41	5720
22	5970	65	5430	41	5738
30	5988	65	5448	41	5764
30	6006	65	5466	41	5790
30	6025	33	5485	41	5816
30	6043	33	5503	41	5842
30	6062	33	5522	41	5860
30	6080	33	5540	41	5886
30	6098	33	5558	41	5912
30	6124	33	5577	41	5931
30	6150	33	5595	45	5949
30	6176	33	5614	45	5975
30	6202	33	5632	45	5994
42	6228	33	5650	45	6020
42	6247	33	5676	45	6038
42	6265	33	5695	45	6056
42	6291	33	5713	45	6075
42	6310	4	5732	45	6093
42	6336	4	5750	45	6119
42	6362	4	5768	45	6138
42	6388	4	5787	45	6156
42	6414	4	5805	45	6174
42	6440	4	5824	50	6193
42	6466	4	5842	50	6219
58	6492	4	5860	50	6245
58	6510	4	5879	50	6263
58	6536	4	5897	50	6282
58	6562	4	5916	50	6308
58	6588	4	5942	50	6334
58	6606	4	5960	50	6360
58	6625	0	5978	50	6378
58	6643	0	5997	50	6396
58	6662	0	6015	50	6422
58	6680	0	6034	45	6448
58	6706	0	6052	45	6474
64	6732	0	6070	45	6493
64	6758	0	6096	45	6519
64	6784	0	6115	45	6537
64	6802	0	6133	45	6556
64	6821	0	6152	45	6574
64	6839	0	6170	45	6592
64	6858	0	6188	45	6611
64	6884	0	6207	45	6629
64	6902	0	6225	45	6648
64	6928	0	6244	45	6666
64	6946	0	6270	45	6684
64	6965	0	6288	35	6703
52	6991	0	6306	35	6721
52	7017	0	6325	35	6740
52	7035	0	6343	35	6758
52	7061	0	6362	35	6776
52	7087	0	6380	35	6795

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52	7139	0	6417	35	6832
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52	7184	0	6454	35	6868
52	7210	0	6472	35	6887
24	7228	0	6498	35	6905
24	7246	0	6524	35	6924
24	7272	0	6550	35	6942
24	7298	0	6576	35	6960
24	7324	0	6594	35	6986
24	7343	0	6620	35	7012
24	7361	0	6646	35	7031
24	7387	0	6672	35	7057
24	7413	0	6698	35	7083
24	7432	0	6724	35	7109
24	7450	0	6743	35	7127
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15	7502	0	6795	35	7172
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15	7546	0	6847	38	7216
15	7565	0	6873	38	7234
15	7583	0	6891	38	7260
15	7602	0	6917	38	7286
15	7620	0	6936	38	7312
15	7646	0	6954	38	7338
15	7664	1	6980	38	7357
15	7683	1	7006	38	7375
15	7709	1	7032	38	7394
15	7727	1	7058	38	7420
15	7746	1	7084	38	7438
15	7772	1	7110	36	7464
15	7798	1	7136	36	7490
15	7816	1	7162	36	7516
15	7834	1	7188	36	7542
15	7853	1	7214	36	7560
15	7871	1	7240	36	7579
15	7890	1	7266	36	7597
15	7916	1	7292	36	7616
15	7934	1	7318	36	7634
15	7952	1	7344	36	7652
15	7971	1	7370	36	7671
15	7997	1	7396	36	7689
15	8015	1	7414	40	7708
15	8041	1	7433	40	7726
15	8067	1	7459	40	7744
15	8093	1	7477	40	7763
15	8112	1	7496	40	7781
15	8130	1	7514	40	7800
15	8148	1	7532	40	7818
15	8167	1	7551	40	7836
15	8185	1	7577	40	7855
15	8204	1	7603	40	7873
10	8230	1	7629	40	7892
10	8248	1	7655	40	7918
10	8266	1	7681	40	7944
10	8285	1	7707	41	7962

10	8303	1	7725	41	7980
10	8322	0	7744	41	7999
10	8340	0	7762	41	8017
10	8366	0	7788	41	8036
10	8392	0	7814	41	8054
10	8418	0	7832	41	8072
10	8444	0	7851	41	8091
10	8462	0	7869	41	8109
10	8481	0	7888	41	8128
10	8499	0	7914	41	8146
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10	8622			32	8253
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10	8674			32	8298
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10	8726			32	8334
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11	8859			23	8468
11	8877			23	8486
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15	9061			23	8685
15	9080			16	8704
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17	9889			19	9650
17	9908			19	9676
17	9926			11	9694
17	9944			11	9713
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				6	10182

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