Recreational Flows

for the Bow River and its tributaries, Alberta

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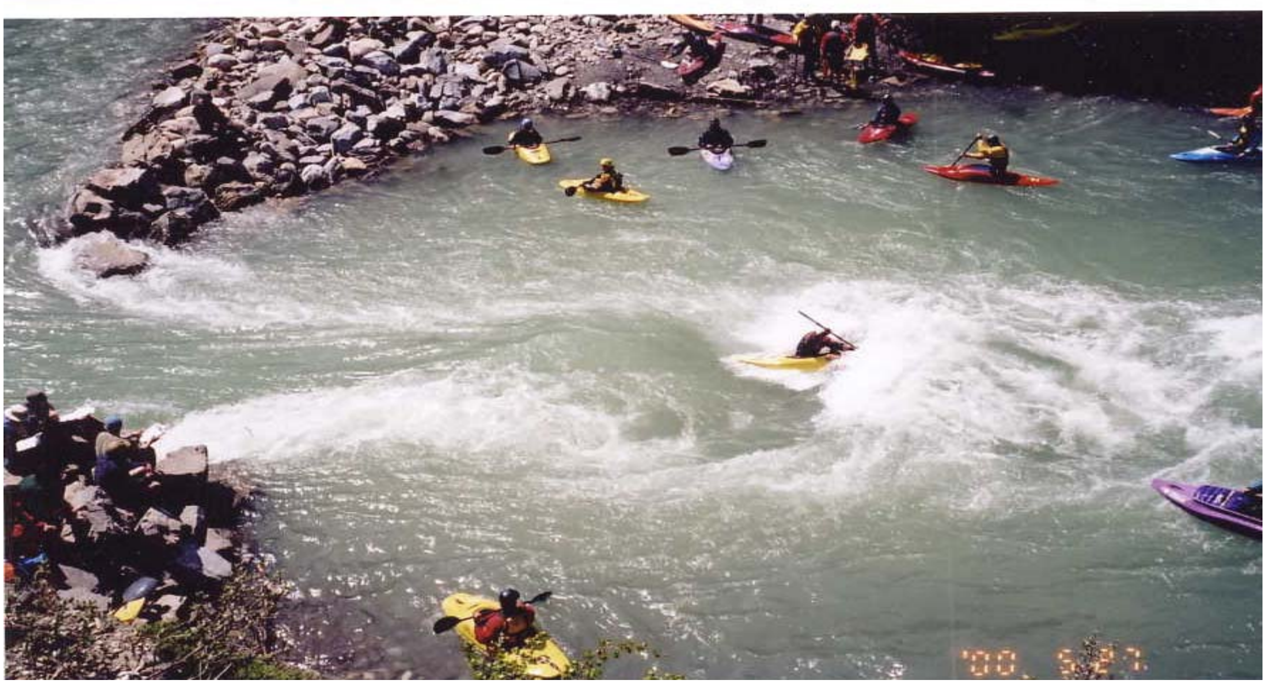

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SUMMARY

The Bow River is Alberta's most extensively dammed river with numerous hydroelectric projects along the upper Bow and its mountain and foothills tributaries. Commencing at Calgary the lower reach becomes progressively dewatered due to three major irrigation diversions. Despite development the Bow River provides an exceptionally valued recreational resource and the reach below Calgary provides one of Canada's most popular trout fisheries. The river and its tributaries are extensively used for recreational paddling with the upper reaches providing advanced whitewater paddling, the middle reaches generally providing intermediate whitewater and the lower reaches providing gradients suitable for novices. The Bow River near Calgary is heavily used due to its proximity to Alberta's largest city while the lower Kananaskis River provides a provincial focus for whitewater recreation.

The present study determined Recreational Flows (RF) for paddling along the sequential reaches of the Bow River and along its principal paddleable tributaries. The study analyzed data from the River Trip Report Card (RTRC) program with 592 cards representing 5942 paddler days submitted from 1983 to 1997. RTRC regression analyses were conducted to determine 'minimal' flows, the low flows that still provide reasonable quality paddling experiences, and 'preferred' flows that represent the low end of the favored flow range.

Results from the RTRC analyses were compared to recommendations from reports and guidebooks and to values from the depth discharge method (DDM), a hydraulic modeling approach and to mean annual discharges. Subsequently, consensus values were derived:

River Reach	Gauge	Minimal Flow m^3/s	Preferred Flow m^3/s
Bow River			
upper Bow River	Lake Louise	12	18
	Banff	25	40
middle Bow River	Calgary	40	60
lower Bow River	Carseland or Bassano	45	65
Highwood River			
upper Highwood River	Diebel's Ranch	13	18
lower Highwood River	Near the Mouth	15	20
Elbow River			
upper Elbow River	Bragg Creek	9	15
lower Elbow River	Below Glenmore Dam	8	14

Tables:

Figures:

INTRODUCTION

The Bow River is the largest tributary of the South Saskatchewan River Basin that also includes the Red Deer and Oldman rivers. The upper reaches of the Bow and its tributaries are extensively dammed for hydroelectric power generation and as the Bow River flows through Calgary and across the prairies, it becomes progressively dewatered due to irrigation diversion. Two major diversion weirs exist, the Western Irrigation District weir that is situated in the City of Calgary and the Bow River Irrigation Diversion weir near Carseland. Further downstream the Bassano Dam exists to permit diversion for the Eastern Irrigation District and during the summer months there are often very limited flows that pass beyond Bassano Dam. The majority of the water consumed in the Basin is used for irrigation. For example in the low flow year 1977, irrigation withdrawals accounted for 95% of the removed water while municipal and industrial demands accounted for 4% and 1%, respectively (Alberta Environment 1984).

With a growing population in the province (1.8% during 2001, Alberta Finance 2002), water demands are likely to continue increasing into the future with growth of the agricultural, municipal and industrial sectors. The growing and aging human population will probably also increase recreational demands that generally provide non-consumptive uses of Alberta's water resources.

The Bow River Basin provides a regional and Provincial recreational resource and is also nationally and internationally significant. The trout fishery is a substantial tourist attraction and 'Canoe Meadows' on the Kananaskis River has been used for international paddling events. About one-half of tourists to Alberta participate in outdoor activities (Research Resolutions 1998) and river recreation provides an important component of the tourism industry.

To provide information to assist river resource managers, a sequence of studies were undertaken to analyze recreational flows (RF) for the regulated and free-flowing tributaries in Alberta's South Saskatchewan River Basin. An initial study investigated the Oldman River Basin and compared and developed methods for RF determination (Rood and Tymensen 2001, Rood et al. 2002b). The second study investigated the Red Deer River that has consistently provided a provincial focus for recreational paddling (Rood et al. 2002a). The present report analyses the third sub-basin that consists of the Bow River and its tributaries.

The Bow River

The upper Bow River

Based on channel geomorphology and recreational opportunities, the Bow River consists of three reaches (Figure 2). The upper Bow River extends from the headwaters in the Rocky Mountains of Banff National Park from which the Bow flows southwest through the towns of Lake Louise, Banff, Canmore and Seebe. Above Lake Louise the gradient is moderately steep producing paddling difficulty reaching grade IV.

The middle Bow River

Through Cochrane and Calgary, the middle Bow River provides characteristics intermediate between the upper and lower reaches. It includes whitewater and flatwater sections and provides a productive trout fishery. Flows are extensively regulated by hydroelectric dams with release schedules that can hinder or facilitate recreational paddling. Through the City of Calgary and further downstream the river becomes more gradual in gradient and provides conditions suitable for novice paddlers. With the exception of the two lethal weirs at Calgary and Carseland and various bridges with in-channel abutments, the river downstream of Bearspaw Dam can be easily navigated by a wide range of paddlers and flows.

The lower Bow River

Below the Carseland weir, the river gradient downgrades further and the paddling characteristics remain mild. At the Bassano Dam a further diversion often dramatically diminishes the downstream flow during the paddling season and the final reach to the confluence with the Oldman River dramatically suffers relative to aquatic and riparian ecosystems as well as paddling opportunities. The cold-water trout fishery declines along the lower reach as a cool-water fishery occurs with northern pike, goldeye and walleye. However, the dewatering downstream of Bassano creates severe stress even for the cool water fish species.

Thus, the Bow River provides a variety of conditions for a range of recreational users. The upper Bow River is quite steep (14.4 m/km in specific areas) with bedrock and boulders that create whitewater conditions. The lower Bow River is much flatter (0.8 m/km) and meanders through Alberta's prairie ecoregion. An excellent fishery through the middle reach can be utilized on its own or in combination with a paddling trip. Numerous access points exist, further encouraging recreational activities through the moderately populated region.

The Highwood River

The Highwood River also presents a diversity of recreation opportunities. It is the second largest river in the basin and based on recreational considerations, can be viewed as an upper and a lower reach.

Originating in Kananaskis Country near the southern end of Banff National Park, the upper Highwood River presents a variety of opportunities for experienced whitewater paddlers. A number of paddleable reaches occur with difficulties ranging from grade II to IV. A sequence of small canyons create interest and a sense of remoteness even though the river is a short drive from Calgary. Downstream of the town of High River, the lower Highwood provides a grade I+ paddling resource that meanders northeasterly to the Bow River. Before the Bow confluence, the Highwood is joined by the Sheep River that provides a small and in some places steep paddleable stream.

The Elbow River

Smaller in size than the Highwood River, the Elbow River presents challenging whitewater in it's upper reach and intermediate whitewater above and through Bragg Creek. The river originates in Kananaskis Country and flows northeast to Calgary where it is dammed to provide Glenmore Reservoir that stores water for Calgary and provides another recreational resource. Below Glenmore Dam, the Elbow flows through residential areas in Calgary and then joins the Bow River at the historic site of Fort Calgary.

The Kananaskis River

The Kananaskis River has progressively increased in popularity amongst paddlers and attracts large numbers of canoeists, kayakers and rafters. In-channel modifications at 'Canoe Meadows' have increased the river's popularity and further modifications are currently being considered. Many local and regional paddling clubs travel to the river for paddling events, partly because flow regulation from Barrier Dam provides some predictability of instream flow conditions.

The present study was undertaken to evaluate recreational flows (RF) for these rivers and for other tributaries of the Bow River Basin. As was the case for the prior analyses of the Oldman and Red Deer river basins, a number of independent methods were applied to achieve confident RF determinations.

METHODS

The study investigated different reaches of Alberta's Bow River and also considered its paddleable tributaries (Figure 2, Tables 1 and 2). The study particularly compared three methods for RF determination:

(1) paddler survey,
(2) expert opinion, and
(3) hydraulic modeling

Paddler Survey

River Trip Report Cards (RTRC) provided the basis for a voluntary, mail-in survey. Post-card style surveys were developed in 1984 (Figure 3) and distributed to paddling clubs in Alberta along with letters inviting participation. The cards were self-addressed with pre-paid mailing to encourage paddler response.

The ratings from the RTRC were converted to numerical scores from 1 (impossibly low) to 7 (dangerously high) with the two ratings for 'river' and 'rapids' being averaged. A suitability score was thus provided with '4' representing 'optimal' flow.

These raw data plots generally produced rather scattered distributions that did not indicate clear thresholds relative to flow suitability. The focus of the current analyses was to determine low flow criteria and consequent analyses considered the lower portion of the response data. A regression method commenced by recognizing the range of flows that were considered by some respondents as lower than ideal. Flows that were consistently judged as 'just right' or higher were above this threshold and these were omitted from subsequent curve-fitting regressions. The remaining data were evaluated through quadratic regression (2nd degree polynomial) since this function produced near-maximal coefficients of determination (r^2) for the previous rivers of the Oldman River Basin (Rood and Tymensen 2001) and the Red Deer River (Rood et al. 2002a). A curved response function was expected since it was anticipated that low flows would provide little improvement over the no-flow point up to the discharge at which the stream was approaching the depth that would consistently float a boat over riffles and permit full paddle blade immersion in most areas. Thereafter, it was expected that the suitability function would increase and then flatten out as the ideal flow range was approached. In two cases, with an abundance of data but there limited low flow data, a linear regression was conducted and this was extrapolated to estimate low flow characteristics.

Following the regression determination, the intercepts of the line of best fit with suitability ratings of 3 and 3.5 were identified and the associated discharges were interpolated to reflect the minimal and preferred flows, respectively (Figures 4-12).

<u>Expert Opinion</u>

To consider expert opinion, paddling guidebooks, and past technical reports for the regional streams were considered.

<u>Hydraulic Modeling - Depth Discharge Method (DDM)</u>

An objective, hydraulic modeling approach was developed and is referred to as the depth criteria, stage-discharge method or more concisely as the depth discharge method (DDM) (Rood & Tymensen 2001, Rood et al. 2002b). Depths of 60 cm (2 ft) and 75 cm (2.5 ft) were applied to estimate minimal and sufficient flows, respectively.

Stage-discharge ratings tables were obtained from Alberta Environment for Water Survey of Canada gauging stations, as well as from Transalta (Table 1 and 2). Subsequently, stage-discharge ratings curves were plotted and discharges that would provide the depth criteria were interpolated.

<u>Historical Hydrologic Data</u>

Historical discharges (Q) were obtained for the river reaches from HYDAT, the hydrologic database established for Water Survey of Canada gauging stations. Discharge (or ‘flow’) data involved daily mean flows

RESULTS AND DISCUSSION

Paddler Survey - River Trip Report Card (RTRC)

A total of 592 RTRC were submitted for the Bow River Basin with 279 for the different reaches of the Bow River. The Highwood, Elbow and Kananaskis Rivers received 94, 89, and 85 cards, respectively. 45 other cards were received for smaller tributaries and irrigation canals (Tables 1 and 2). These response rates were considered generally sufficient for RF evaluation for the Bow, Elbow, Highwood River and Kananaskis Rivers but data limitations occurred for dammed reaches due to (1) insufficient low flow information, and (2) diurnal flow pulsing ('peaking') that complicated analyses. The remaining tributaries contained insufficient RTRC for RF analyses.

The RTRC represented an average of 10 boater days per card. Numbers of boaters were quite consistent across the different river reaches, with a proportionately larger number representing the Bow River downstream of the Bearspaw Dam to the Carseland Weir (129), while the two sections below the Carseland Weir only received 3 submissions combined. The reason behind the lack of submissions for the Bow River downstream of the Carseland Weir is unknown. Paddlers can be frequently seen throughout the lower reaches and the trout fishery attracts many people to the area.

For analysis of the RTRC, the upper Bow River was broken down into three separate segments, due to the large increase in mean annual discharge that occurs downstream of Lake Louise and the changing gradients of the reach. The reach was divided into the segments upstream of Lake Louise, between Lake Louise and Banff, and downstream from the town of Banff. Each of the segments were fairly well represented with 22, 28 and 40 RTRC respectively. The segments were limited in the extent of low flow data, which consequently decreases confidence of the minimal and preferred flow values.

The middle reach of the Bow River houses numerous water control structures and impedes paddlers by forcing them to portage around many of the dangers and impassable areas. Predictable flows are released from the hydroelectric dams and users can partially plan recreation activities around the flows which best suit their particular interests. The regulation of flows can thus both improve and diminish the overall paddling experience. Above Calgary the

Bearspaw Dam is operated as a re-regulating dam, and reduces the diurnal flow pulsing associated with hydroelectric power generation.

The lower reach of the Bow River had minimal data submission. This probably largely reflects the situation in which severe dewatering occurs in the summer months of many years. There are often limited flows that pass beyond Bassano Dam due to the diversions for irrigation.

The Highwood River was broken down into two reaches (upstream and downstream of High River) and each received sufficient RTRC for a regression analysis. The Elbow River was broken into two segments (upstream and downstream of Glenmore Reservoir) with whitewater being abundant upstream but limited along the downstream reach. Both segments were well represented by the RTRC with a wide range of flows, thus giving confidence to the results. Despite the different paddling situations, the upper and lower sections produced similar values for minimal and preferred flows.

For the Highwood and Elbow Rivers, the RTRC minimal flows were very similar to the mean annual discharges of the reaches (Table 6). For the larger sized Bow River, with the exception of the reach upstream of Banff, the preferred flows as determined by the RTRC were more similar to the mean annual discharges (Tables 5 and 7). We previously determined that the mean annual discharge provided a close estimate of minimal flows for small and medium-sized rivers but this relationship was less applicable to larger rivers (Rood and Tymensen 2001, Rood et al. 2002). This same pattern applies for the Highwood and Elbow rivers as well as for the uppermost segment of the Bow River.

With 85 RTRC submissions for the Kananaskis River, data were sufficient for the regression analysis for the reach from Barrier Dam through 'Canoe Meadows' to the Bow River. However Barrier Dam's diurnal flow pulsing complicated the comparative analysis. Daily mean flows are inappropriate for analyses since these combine the higher flow that would have occurred during the paddling activity and a very low flow when power was not being generated.

Expert Opinion

For the RF approach involving expert opinion, the present study considered the various guidebooks and past reports that dealt with any of the streams being assessed in this study.

Regional guides were identified and one was found to provide information regarding recommended flow levels that were applicable to RF determination.

The extent of reports including recommended flows throughout the Bow River Basin was quite limited. This was surprising since more extensive reports are available for the Oldman and Red Deer rivers and the Bow River flows through Alberta's largest city and is heavily used by paddlers (as evidenced by a higher number of RTRC responses).

Clipperton (1998) provided an interesting study intended to determine RF for a section of the Bow River between the Ghost Dam and Cochrane. Various approaches were integrated but there were limited user responses during low flow periods, reducing the capacity to determine minimal flow values.

White (1999) studied the reach of the Bow River between the Bearspaw Dam and Carseland and applied a user survey to determine minimal and preferred values. While providing some useful information that analysis was also limited by the lack of low flows during the study period. Thus, the Bow River through Calgary is extensively flow regulated and this substantially reduces peak flows and dramatically increases low flows through the summer. Consequently, summer flows through Calgary are almost always sufficient for recreational paddling and are even sufficient for the motorized jet-boat that is regularly on the river as part of the fire department's river safety and rescue program.

<u>Hydraulic Analysis the Depth, Discharge Method (DDM)</u>

A number of previous researchers have applied various hydrometric methods for RF analysis. Whittaker et al. (1993) categorized these approaches as 'prediction-based modeling methods'. We determined that the depth discharge method (DDM) was reasonably easy to apply and provided results for streams in the Oldman River Basin that were very consistent with values from various subjective approaches (Rood et al. 2002b).

The DDM was applied at various hydrometric stations throughout the Bow River Basin with the Bow, Highwood and Elbow being rated at multiple hydrometric stations. The values across the gauges represented the reaches quite well, and for the most part the values achieved through the DDM analyses were similar to the minimal values obtained through the RTRC. A notable exception however is that the upper Elbow river received a value substantially higher than the lower Elbow (upper = 23, lower = 9, Table 6). The upper Elbow value seems to be slightly distorted as it is different from the minimal RTRC and Smith's (1996) value. This difference may be attributable to the channel geomorphology at the Bragg Creek hydrometric station not being characteristic of the typical channel geomorphology found throughout the reach. The Ghost River also appeared to be poorly represented by its gauge (Near Waiporous Creek) as the minimal value determined was 10 fold that of its average annual discharge.

Comparisons across RF Methods

The different subjective appraisals provided relatively consistent recommendations regarding minimal and preferred instream flows for recreational paddling (Table 5-8). Smith's (1995) estimates of minimal flows focused on the whitewater reaches of the Bow River and its tributaries, thus only covering the upper segments of many of the reaches. Bloomfield (1984) only recommended flows for the lower segments of the Bow River and its tributaries were not considered. Clipperton (1998) and White (1999) provided suggestions relating to particular segments of the middle Bow River, while Taylor studied the lower Elbow River. Thus, comparisons across prior reports were limited. Since the RTRC values reflect estimates from hundreds of paddlers, these may reflect a broad range of assessment views.

A strength of the depth discharge method (DDM) is that it is based on physical characteristics and avoids subjective valuation. However, this modeling approach would only be useful if the output is consistent with subjective assessment that is the ultimate aim of the RF analysis. This was the case in the present study as the DDM estimates for both minimal and preferred flows were consistently very close to estimates based on the subjective methods. In the prior development of the DDM with the streams of the Oldman River Basin, this hydraulic modeling approach was determined to be inappropriate for large rivers such as the Oldman River through Lethbridge (Rood and Tymensen, 2001). A subsequent study on the lower Red Deer River revealed this relationship not to be the case (Rood et al. 2002). With regards to these two studies, the Bow River held the relationship quite well through its upper section and then deteriorated throughout the middle section and continued to do so in the lower section. The smaller sized tributaries however held quite constant with the relationship between subjective approaches and the DDM.

As indicated, the recreational flows of the present study were also compared to the recommendations from four prior technical studies. The values of the current analyses were quite consistent with those determined by Bloomfield et al. (1984) as part of the South Saskatchewan River Basin Planning Program. Those values were based on assessments of 'the minimum desirable depth for paddling a canoe', a value of 60 cm. Meetings with canoeists and previous literature further combined to refine the suggested minimal flow requirements.

Earlier researchers had investigated the application of simple ratios between paddleable flows and broader hydrologic characteristics, particularly the mean annual discharge (Corbett 1990, Tennant 1976). Rood and Tymensen (2001) also investigated the relationships among rivers in southern Alberta and found there was a very close correlation between mean annual discharge (Q) and the aggregate estimate of minimal flow for recreational paddling along small to mid-sized rivers. This consistency was also observed in a study of the Red Deer River Basin (Rood et al. 2002a). The correlation existed again for the Bow River Basin amongst its smaller sized tributaries.

The relationships between paddleable flows and mean annual discharge probably result from fundamental proportionality between stream flow and channel geometry. The size of an alluvial stream channel is a particular physical consequence of stream flow and associated with this size, typical depth characteristics will result. It is thus reasonable that basic relationships would exist between typical depth and flow.

TRIBUTARIES

The Bow River owes its relatively high discharge rates to the many tributaries found throughout the basin. While some of the major ones have already been discussed, there exist some less obvious ones that are not frequented as much regarding recreation.

Smith (1995) describes three reaches that received no RTRC responses. These were the Pipestone River, Redearth Creek and Healy Creek. Paddling seasons for these reaches are often short as they are small streams that are uncontrolled and fed by snowmelt and runoff.

The Ghost River, Fish Creek and Waiporous Creek are probably slightly more commonly used by paddlers with 2, 6 and 6 RTRC submissions, respectively. The smaller number of responses for these reaches is probably representative of the short paddling seasons and small size (mean discharges of 3.3, 1.2 and 2.2 m^3/s, respectively). The plotted ratings table for the Ghost River produced unbelievably high minimal and preferred flow values, given the small stream size.

Although the Sheep River received 20 RTRC responses there were few submissions for low flow trips, preventing determination of minimal and preferred flows.

CONCLUSIONS AND RECOMMENDATIONS

The present study demonstrated very close agreement in estimates of recreational flows (RF) for different rivers located in the Bow River Basin based on different methods. Different subjective approaches generated very similar values that were also consistent with estimates based on a physical hydrometric method involving a combination of depth criteria and stage-discharge analysis. This strong agreement supports the validity of all of these methods. Further, the consistency across methods strengthens the confidence in the values that were determined. The final close relationship between mean annual discharge and minimum flow for recreational boating was unexpected and also provides another objective physical estimate that may be useful.

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Table 1. Characteristics of reaches of the Bow River, Alberta.

River Reach	Discharge (mean Q) (m^3/s)	Gradient (m/km)	Grade of Difficulty	Hydrometric Gauge[a]	River Trip Report Cards (RTRC) # Cards	# Boaters
Bow River						
upper reach						
above Lake Louise	11.6	14.4	III-IV	Lake Louise (1910)	22	193
Lake Louise to Banff	40.1	2.6	II	Banff (1909)	28	291
Banff to Seebe	45.1	2.3	II	Near Seebe (1923)[b]	40	488
middle reach						
Seebe to Bearspaw Dam	87.0	2.3	I-IV	Below Bearspaw Dam (1983)[c]	57	520
Bearspaw Dam to Carseland Weir	91.6	0.8	I	Calgary (1911)	129	1634
lower reach						
Carseland weir to Bassano Dam	133	0.8	I	Carseland (1910)	2	16
Bassano Dam to the Oldman confluence	116	0.8	I	Bassano (1910)	1	4

[a] This represents the hydrometric gauge used for data analysis for each reach and first year of hydrometric record is included.
[b] This gauge only utilizes data up to 1998.
[c] The gauge lies below the reach which it represents.

Table 2. Characteristics of tributaries of the Bow River, Alberta.

River Reach[a]	Discharge (mean Q) (m^3/s)	Gradient (m/km)	Grade of Difficulty	Hydrometric Gauge[b]	River Trip Report Cards (RTRC) # Cards	# Boaters
Highwood River						
upper reach above High River	12.6	5.9	II-IV	Diebel's Ranch (1950)	69	714
lower reach below High River	18.8	1.7	I+	Near the Mouth (1910)	25	290
Elbow River						
upper reach above Glenmore Dam	10.2	8.6	II-IV	Bragg Creek (1934)	69	445
lower reach below Glenmore Dam	8.1	6.6	I+	Below Glenmore Dam (1908)	20	307
other tributaries						
Kananaskis River	13.7	5.2	II+	Below Barrier Dam (1975)[c]	85	721
Sheep River	5.7	10.1	II-IV	Black Diamond (1909)	20	157
Ghost River	3.3			Above Waiporous Creek (1983)	2	12
Waiporous Creek	2.2			Near the Mouth (1966)	6	36
Fish Creek	1.2		II	Near Priddis (1908)	6	21
others					11	93
total (including the Bow)					592	5942

[a] Sequenced in a decreasing order based upon magnitude of mean annual discharge (Q).
[b] This represents the hydrometric gauge used for data analysis for each reach and first year of hydrometric record is included. The gauge data is complete up to 1999.
[c] This gauge only utilizes data up to 1998.

Table 3. Water control structures affecting flows along the reaches assessed in the Bow River Basin.

Number	Name	Year Constructed	Purpose
1	Interlakes Dam	1955	Hydroelectric power generation
2	Pocaterra Dam	1955	Hydroelectric power generation
3	Barrier Dam	1947	Hydroelectric power generation
4	Kananaskis Dam	1913	Hydroelectric power generation
5	Horseshoe Dam	1911	Hydroelectric power generation
6	Ghost Dam	1929	Hydroelectric power generation
7	Bearspaw Dam	1954	Hydroelectic Power generation and Flow regulation
8	Glenmore Dam	1932	Water supply for Calgary
9	Calgary WID Weir	1912	Irrigation
10	Womans Coulee Weir	1933	Irrigation
11	Little Bow Weir	1910	Irrigation
12	Carseland Weir	1918	Irrigation
13	Bassano Dam	1914	Irrigation

Table 4. Publications related to recreational paddling in the Bow River Basin.

Author	Type	Year	Description
Bloomfield and 5 others	Report	1984	An analysis of preferred river flows for rivers in the South Saskatchewan River Basin based upon hydraulic criteria
Clipperton, G.K.	Report	1998	An analysis of minimal and preferred flows for a variety of recreation types on the Bow River between the Ghost Dam and Cochrane.
MacDonald, J.	Guide Book	1985	Describes river characteristics and descriptions of features encountered while paddling. Does not suggest flows.
Smith, S.	Guide Book	1995	Describes whitewater reaches, as well as the optimal paddling seasons and suggested flows.
Taylor, A.	Report	1999	An analysis of minimal and preferred flows for paddling on the upper Elbow River between the Bearspaw Dam and Calgary.
Travel Alberta	Guide Book	1978	Describes river reaches of the South Saskatchewan River Basin by providing physical characteristics.
White	Report	1999	An analysis of minimal and preferred flows for a variety of recreation types on the Bow River between the Bearspaw Dam and Calgary.

Table 5. Minimal flows for recreational paddling of reaches of the Bow River as determined by subjective methods and by the depth, discharge method (DDM), with a depth criterion of 60 cm, along with mean annual discharges and various ratios of these parameters. Q = discharge. Outlined numbers represent questionable values.

River Reach	RTRC	DDM	Bloomfield	Other	Mean Q	Consensus Value
	m^3/s					
Bow River						
upper reach						
above Lake Louise	12	14			11.6	12
Lake Louise to Banff	9	6		40a	40.1	25
Banff to Seebe			30	40a	45.1	
middle reach						
Seebe to Bearspaw Dam	25		30	59b	87	40
Bearspaw Dam to Carseland Weir	46	34	30-40	80c	91.6	40
lower reach						
Carseland weir to Bassano Dam		150	40		133	45
Bassano Dam to the Oldman confluence		50	40		116	45

Values in boxes are considered inaccurate.
a = Smith, b = Clipperton, c = White

Table 6. Minimal flows for recreational paddling of tributaries of the Bow River as determined by subjective methods and by the depth, discharge method (DDM), with a depth criterion of 60 cm, along with mean annual discharges and various ratios of these parameters.
Q = discharge. Outlined numbers represent questionable values.

River Reach	RTRC	DDM	Other	Mean Q	Consensus Value
	m^3/s			m^3/s	
Highwood River					
upper reach above High River	5	12	20a	12.6	13
lower reach below High River	12	15		18.8	15
Elbow River					
upper reach above Glenmore Dam	8	23	12a	10.2	9
lower reach below Glenmore Dam	8	9	6-8b	8.1	8
other tributaries					
Kananaskis River		7		13.7	12
Sheep River		2	10	5.7	6-7
Ghost River	33	33		3.3	
Waiporous Creek		3		2.2	3
Fish Creek		7		1.2	

Values in boxes are considered inaccurate.
a = Smith, b = Taylor

Table 7. Preferred flows for recreational paddling along reaches of the Bow River as determined by various subjective methods and by the depth, discharge method (DDM) using a depth criterion of 75 cm. RTRC = River Trip Report Card. Outlined numbers represent questionable values.

River Reach	RTRC	DDM	Others	Consensus Value
	m³/s			
Bow River				
upper reach				
above Lake Louise	15	20		18
Lake Louise to Banff	15	9		
Banff to Seebe	55			
middle reach				
Seebe to Bearspaw Dam	60		113[a]	
Bearspaw Dam to Carseland Weir	80	50	150[b]	
lower reach				
Carseland weir to Bassano Dam		210		
Bassano Dam to the Oldman confluence		70		

[a] Clipperton
[b] White

Table 8. Preferred flows for recreational paddling along tributaries of the Bow River as determined by various subjective methods and by the depth, discharge method (DDM) using a depth criterion of 75 cm. RTRC = River Trip Report Card. Outlined number represent questionable values.

River Reach	RTRC	DDM	Taylor	Consensus Value
	m³/s			
Highwood River				
upper reach above High River	12	20		18
lower reach below High River	17	23		20
Elbow River				
upper reach above Glenmore Dam	14	[37]	15	15
lower reach below Glenmore Dam	14	14		14
other tributaries				
Kananaskis River	7	13		
Sheep River		5		
Ghost River				
Waiporous Creek		7		
Fish Creek		12		

Figure 2. Map of the Bow River Basin.

Figure 2. Map of the Bow River Basin. Water control structures are signified by numbers and are identified in Table 2.
* = Hydrometric gauges.

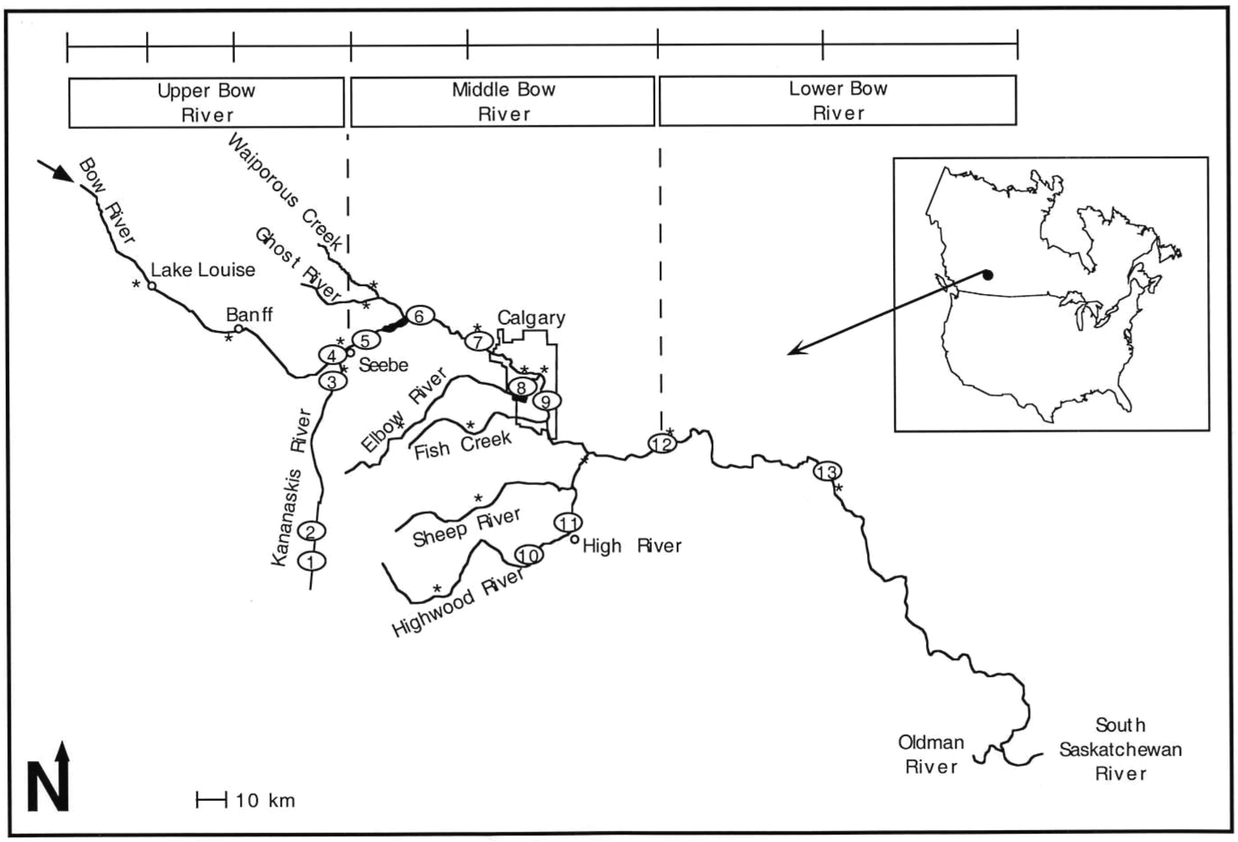

Figure 3. The River Trip Report Card (RTRC).

RIVER TRIP REPORT

RIVER(S)________ PUT IN POINT________ DATE ______ TIME______

PULL OUT POINT ________ DATE ______ TIME______ NO. IN PARTY______

NO. AT EACH SKILL LEVEL: Beginner ____ Novice____ Intermediate____ Advanced____

NO. OF EACH CRAFT: Open Canoe____ Covered Canoe____ Kayak____ Raft____ Other ____

WATER LEVEL GENERAL: Impossibly Low ☐ Much Too Low ☐ Low ☐

Just Right ☐ A Little High ☐ Much Too High ☐ Dangerously High ☐

WATER LEVEL AT RAPIDS: Impossibly Low ☐ Much Too Low ☐ Low ☐

Just Right ☐ A Little High ☐ Much Too High ☐ Dangerously High ☐

ACTIVITIES: Fishing ☐ Swimming ☐ Camping (locations) ________

Other ________

CLARIFICATIONS AND COMMENTS: ________

04/87/3M

Figure 4. Plotted data for the River Trip Report Cards (RTRC) submitted for the upper Bow River upstream of Lake Louise. The dashed lines represent the suitabilities that correspond with the minimal flows (suitability = 3) and the preferred flows (suitability = 3.5). Additional values were provided for higher discharges but are not included in the plot shown.

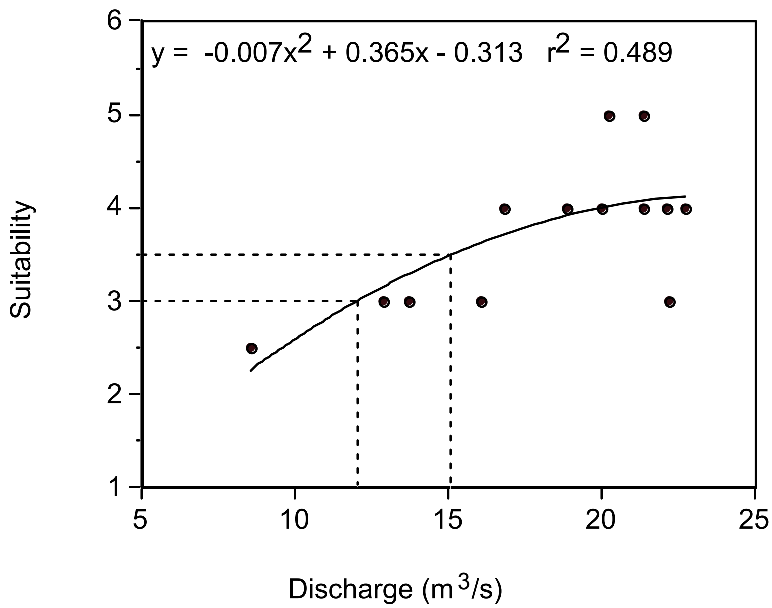

Figure 5. Plotted data for the River Trip Report Cards (RTRC) submitted for the upper Bow River between Lake Louise and Banff. Additional values were provided for higher discharges but are not included in the plot shown.

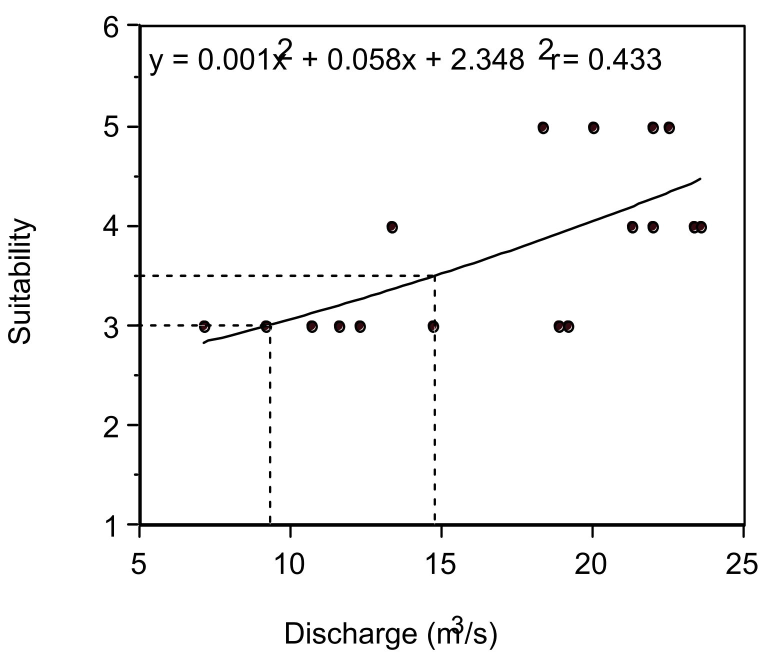

Figure 6. Plotted data for the River Trip Report Cards (RTRC) submitted for the upper Bow River between Banff and Seebe. Additional values were provided for higher discharges but are not included in the plot shown.

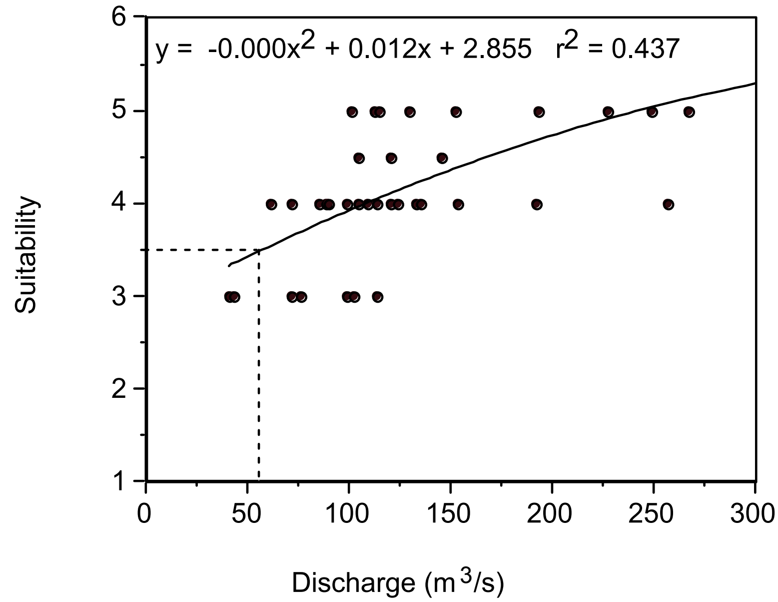

Figure 7. Plotted data for the River Trip Report Cards (RTRC) submitted for the middle Bow River between Seebe and the Bearspaw Dam. Additional values were provided for higher discharges but are not included in the plot shown. Due to the abundance and nature of the data, this graph was not subjected to a polynomial regression like the others, but a linear regression instead.

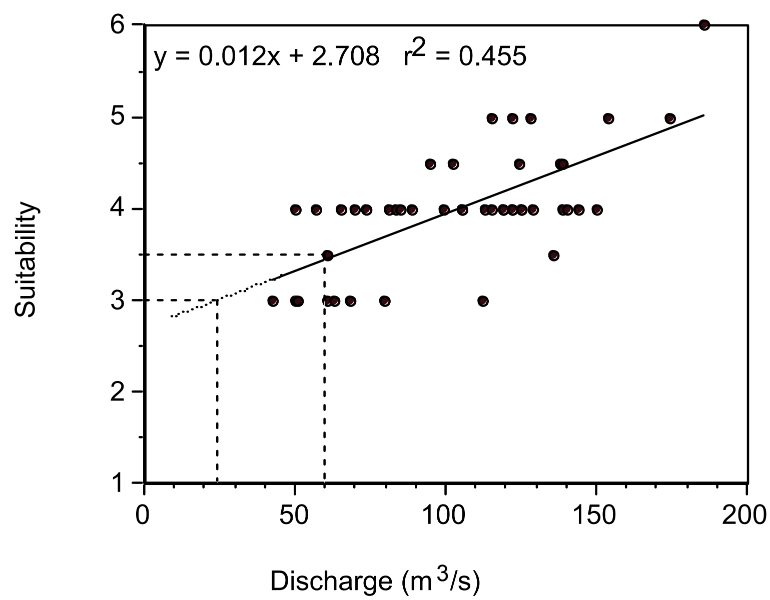

Figure 8. Plotted data for the River Trip Report Cards (RTRC) submitted for the lower Bow River between the Bearspaw Dam and the Carseland Weir. Additional values were provided for higher discharges but are not included in the plot shown. Due to the abundance and nature of the data, this graph was not subjected to a polynomial regression like the others, but a linear regression instead.

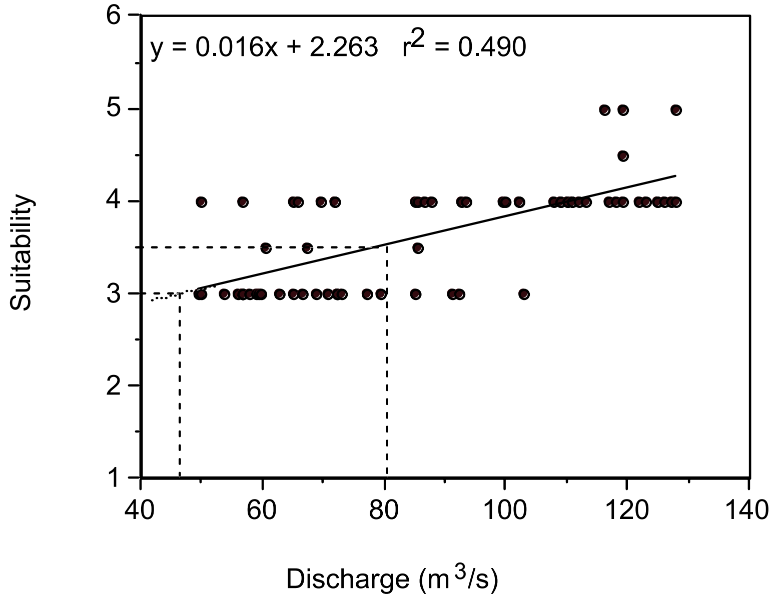

Figure 9. Plotted data for the River Trip Report Cards (RTRC) submitted for the upper Highwood River upstream of High River. Additional values were provided for higher discharges but are not included in the plot shown.

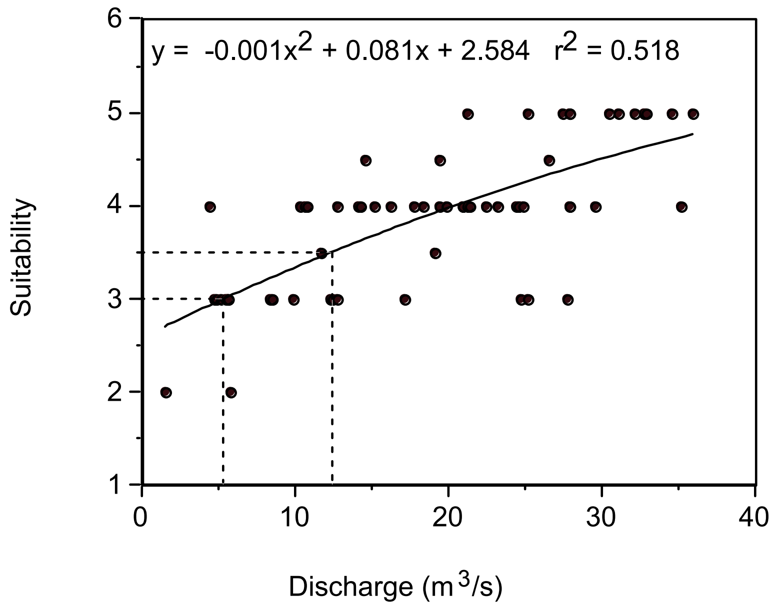

Figure 10. Plotted data for the River Trip Report Cards (RTRC) submitted for the lower Highwood River downstream of High River. Additional values were provided for higher discharges but are not included in the plot shown.

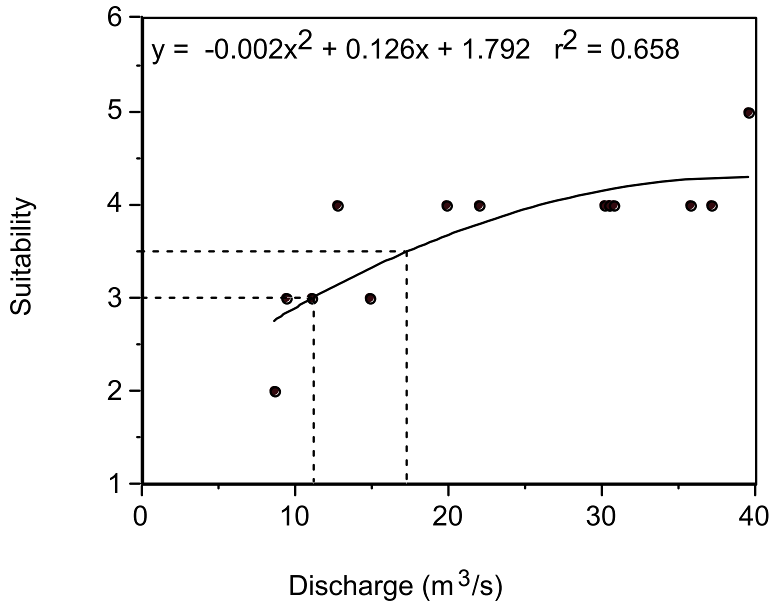

Figure 11. Plotted data for the River Trip Report Cards (RTRC) submitted for the upper Elbow River upstream of Glenmore Reservoir. Additional values were provided for higher discharges but are not included in the plot shown.

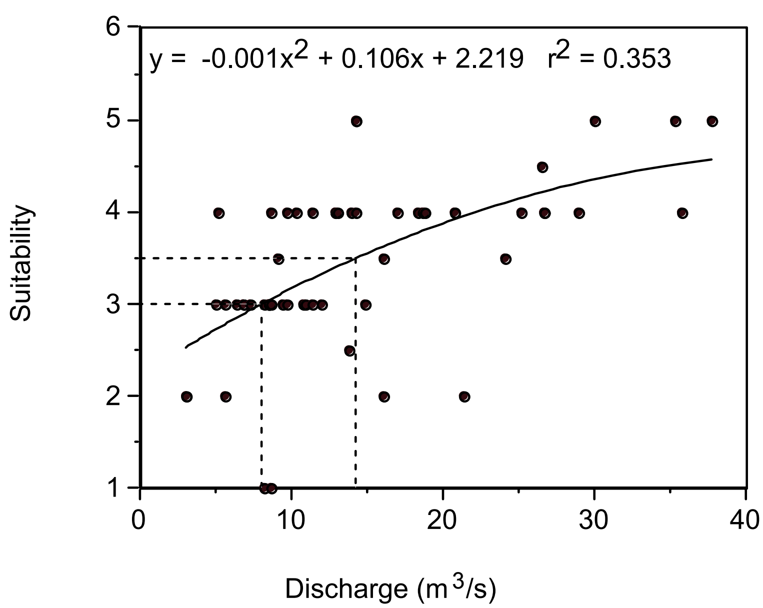

Figure 12. Plotted data for the River Trip Report Cards (RTRC) submitted for the lower Elbow River downstream of Glenmore Dam. Additional values were provided for higher discharges but are not included in the plot shown.

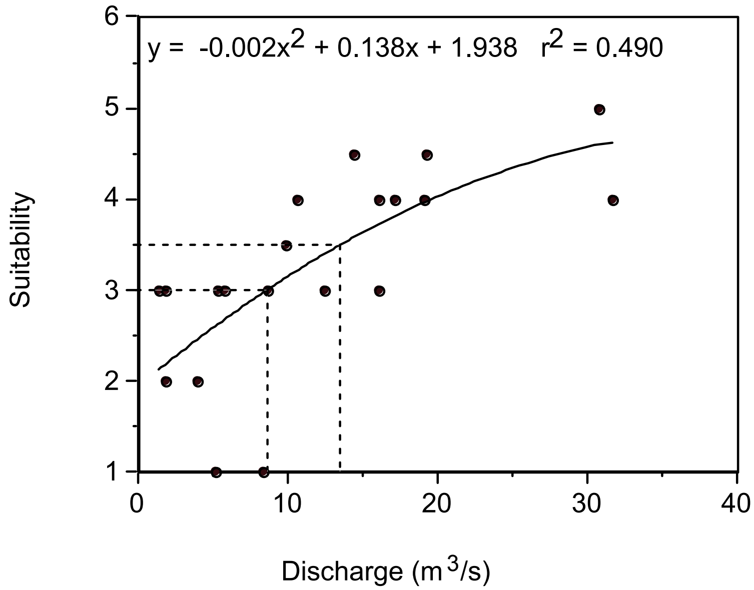

Figure 13. Plotted ratings data for the Bow River at the Lake Louise hydrometric gauge. The dashed lines represent the stages (depths) that provide a minimal flow (0.6 m stage) and preferred flow (0.75 m stage).

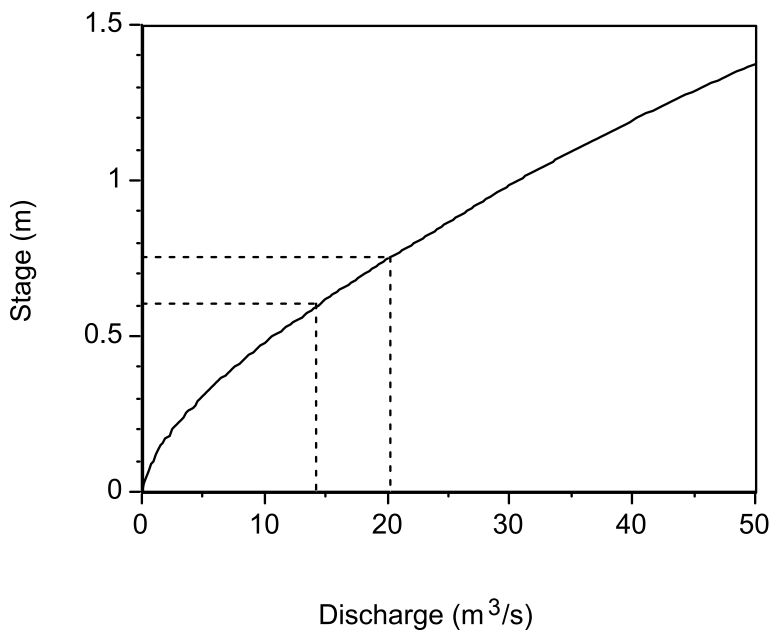

Figure 14. Plotted ratings data for the Bow River at the Banff hydrometric gauge.

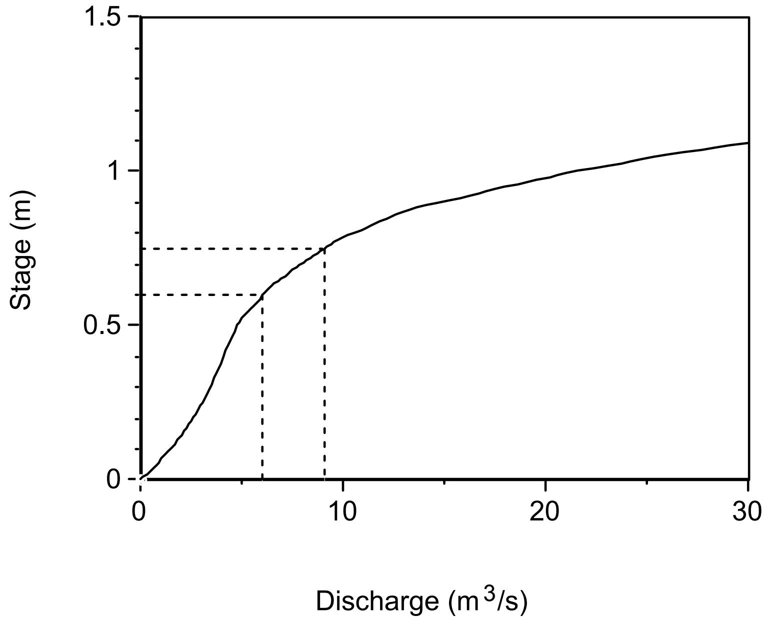

Figure 15. Plotted ratings data for the Bow River at the Calgary hydrometric gauge.

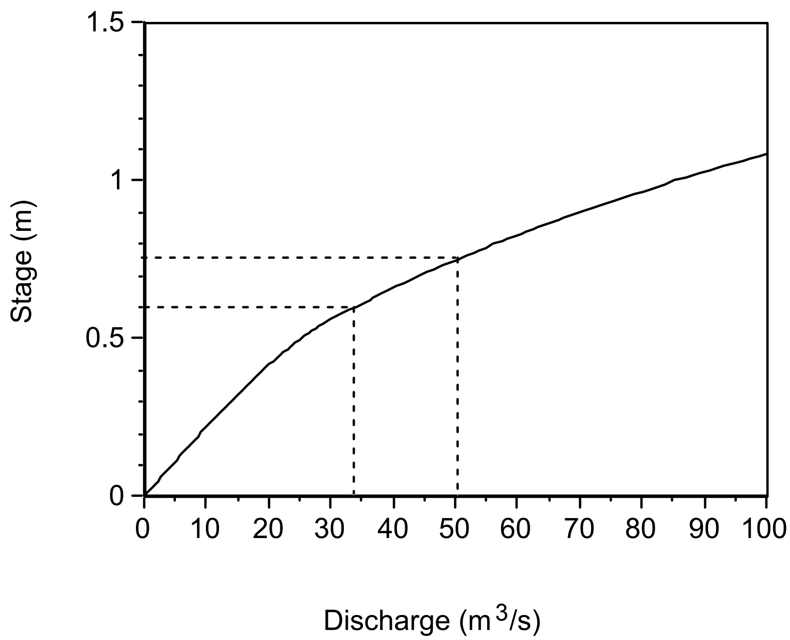

Figure 16. Plotted ratings data for the Bow River at the Carseland hydrometric gauge.

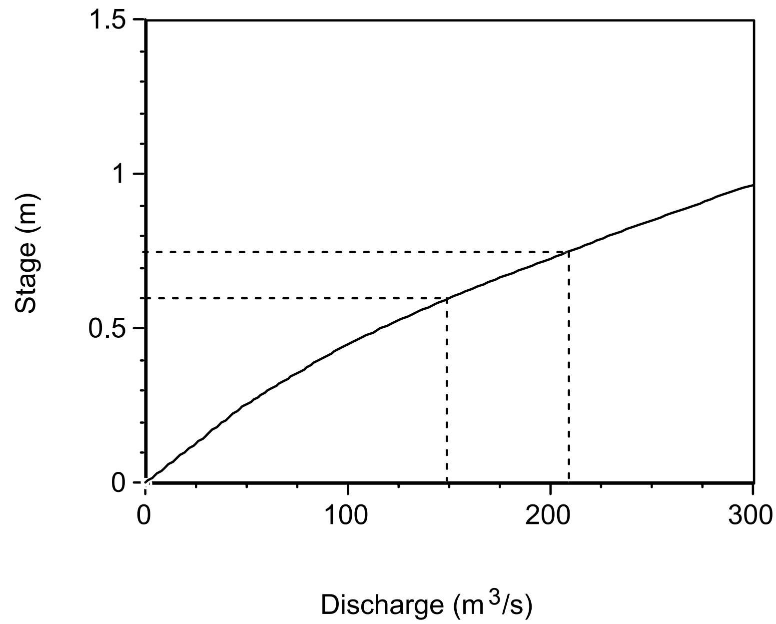

Figure 17. Plotted ratings data for the Bow River at the Bassano hydrometric gauge.

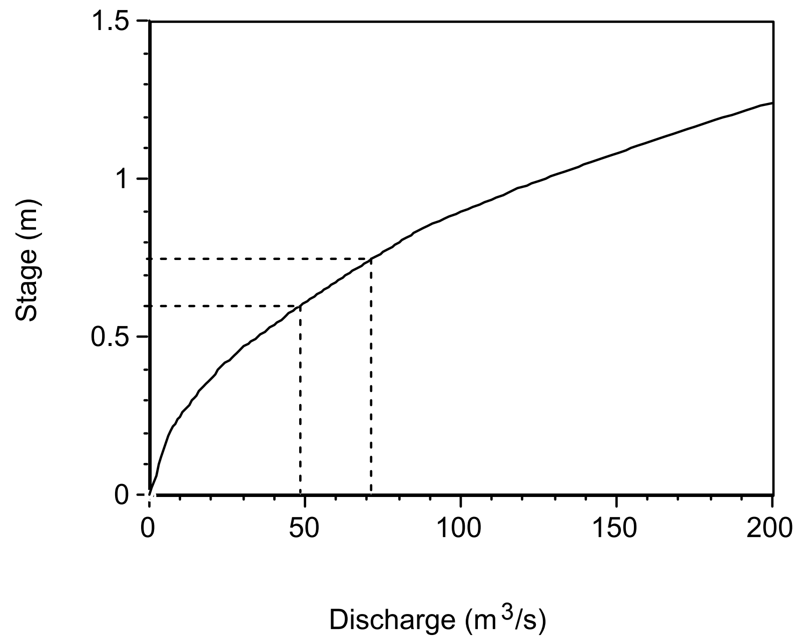

Figure 18. Plotted ratings data for the Highwood River at the Diebel's Ranch hydrometric gauge.

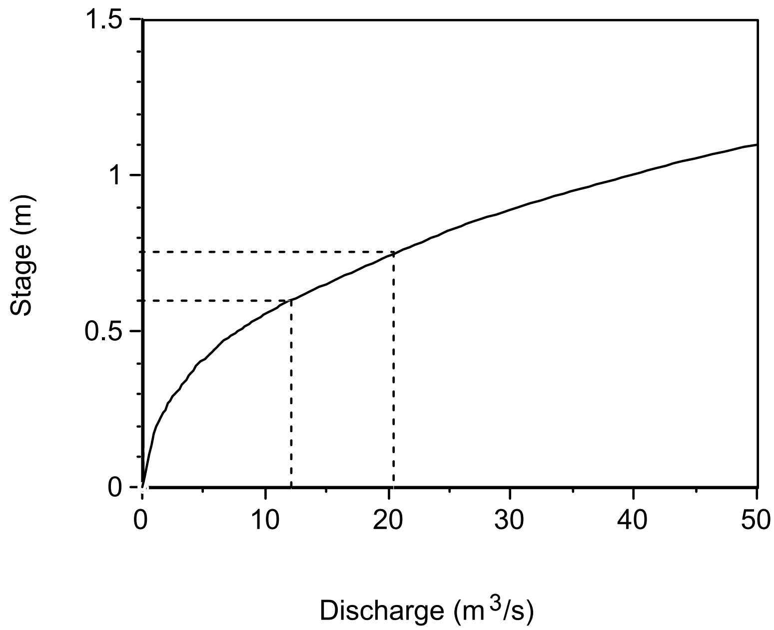

Figure 19. Plotted ratings data for the Highwood River at the Near the Mouth hydrometric gauge.

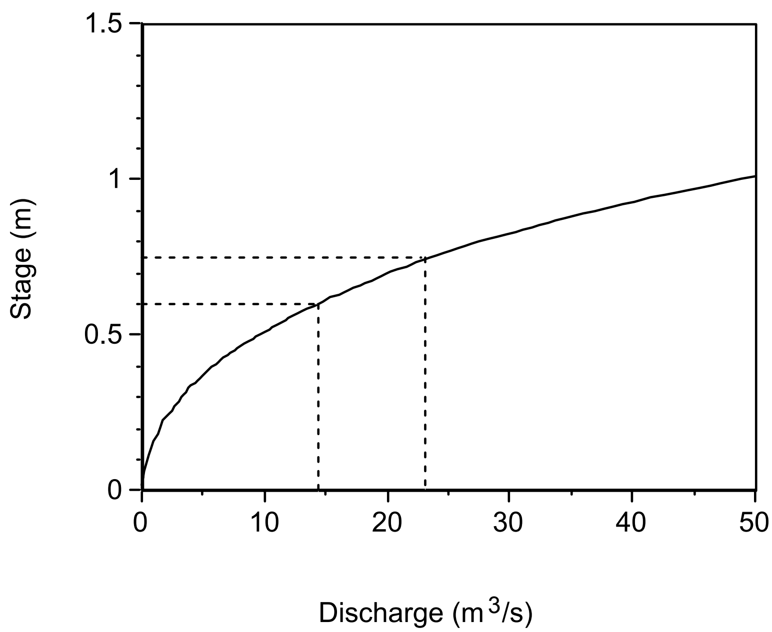

Figure 20. Plotted ratings data for the Elbow River at the Bragg Creek hydrometric gauge.

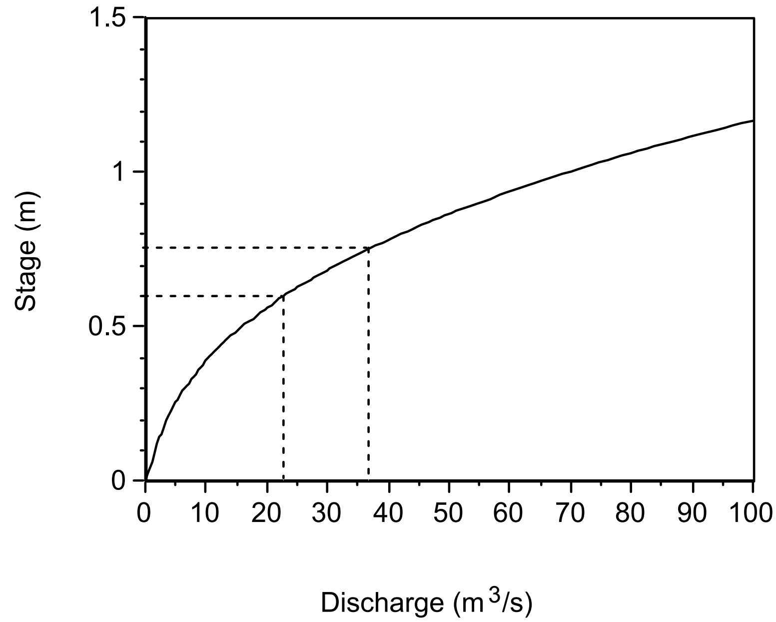

Figure 21. Plotted ratings data for the Elbow River at the Below Glenmore Dam hydrometric gauge.

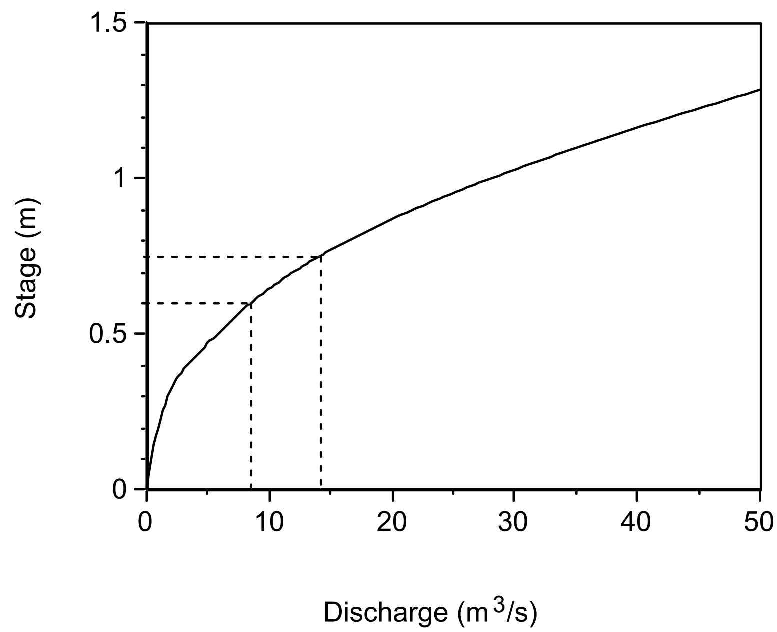

Figure 22. Plotted ratings data for the Kananaskis River at the Barrier Dam hydrometric gauge.

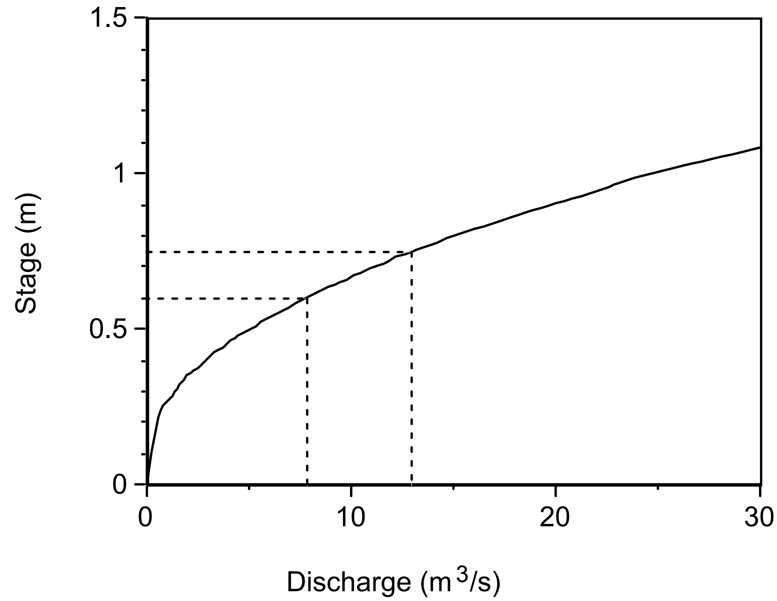

Figure 23. Plotted ratings data for the Sheep River at the Black Diamond hydrometric gauge.

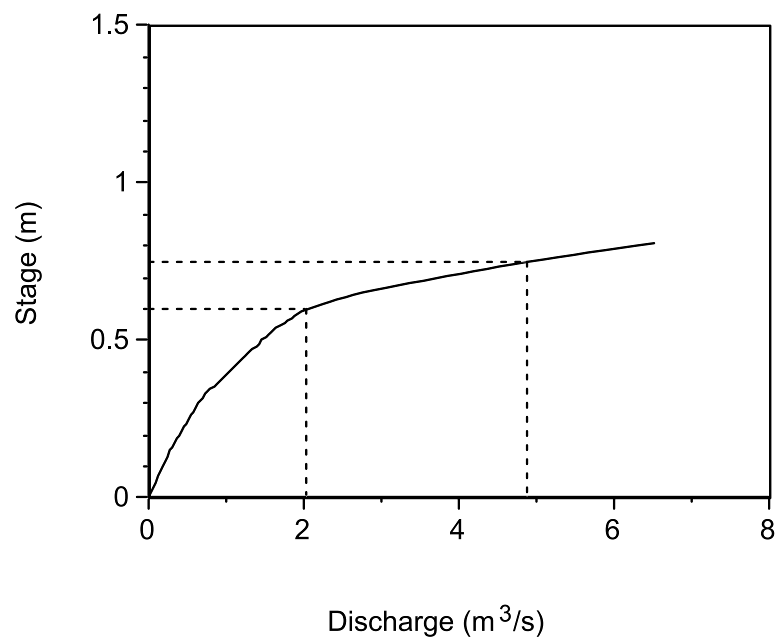

Figure 24. Plotted ratings data for the Ghost River at the Near Waiporous Creek hydrometric gauge.

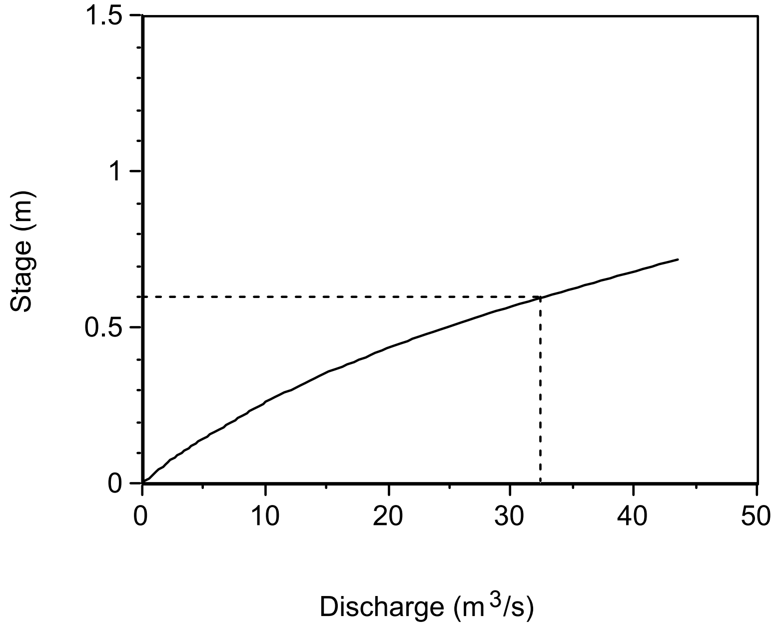

Figure 25. Plotted ratings data for Waiporous Creek at the Near the Mouth hydrometric gauge.

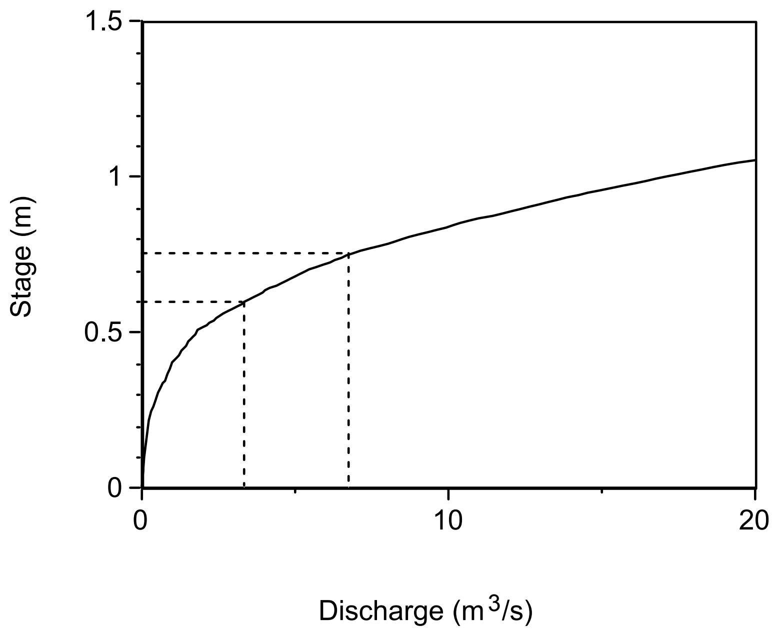

Figure 26. Plotted ratings data for Fish Creek at the Near Priddis hydrometric gauge.