Appendix A
Channel Depth Analysis of the Lower Taku River

Prepared for
Redfern Resources Ltd.

Submitted by
Gartner Lee Limited

July 2007

Gartner Lee

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Reference: **GLL 70-142**

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July 30, 2007

Tim Davies
Manager, Environmental and Regulatory Affairs
Redfern Resources Ltd.
800-1281 West Georgia St.
Vancouver, BC V6E 3J7

Dear Mr Davies:

Re: GLL 70-142 — Channel Depth Analysis of the Lower Taku River

Please find attached a copy of our report entitled, "Channel Depth Analysis of the Lower Taku River". This report has been prepared as an addendum to *Volume 1, Project Description of the Air Cushion Barge Transportation System*, July 2007. Please do not hesitate to contact me at (867) 633-6474 ext. 5740 should you have any questions. Thank you for the opportunity to work on this very interesting project.

Yours very truly,
GARTNER LEE LIMITED

Chad Davey, M.Sc.
Fluvial Geomorphologist

Attach.

CD:gc

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A. "Taku River Hydrographic Survey", Sandwell Inc., 1995

1. Introduction

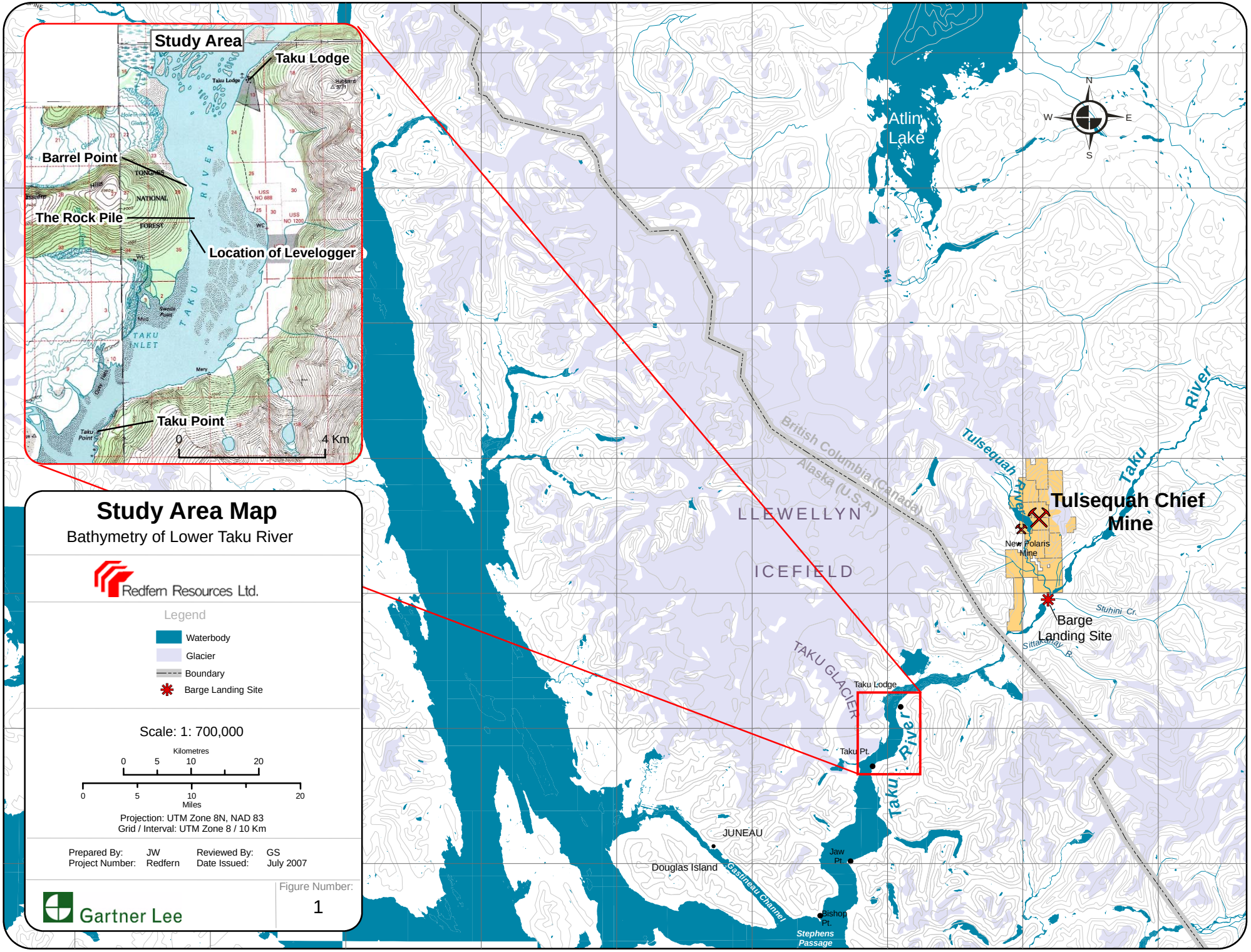
A barging operation has been proposed along the Taku River to transport mine concentrate and supplies to and from the Tulsequah Chief Mine site to Juneau, Alaska. The proposed operation would utilize an air cushion barge towed by either a shallow draft tug or an amphibious tractor (amphitrac), depending of season and/or river levels. The majority of the route between the proposed barge landing on the Taku River and Juneau, Alaska should be sufficiently wide and deep enough to allow the vessels to operate fully aquatically during the open water season. However, a tidally influenced section of the lower Taku River is an area of shallow water during low tide and/or low river discharge conditions. This area is known as the “sand flats” and is located along a reach of river extending from Taku Lodge to Taku Point (Figure 1).

The purpose of this report is to present the results of an analysis of channel depths through this section of the river, coupled with a tide and river stage/discharge analysis along the aforementioned reach of river. Specifically, the goal of the study was to identify the specific combinations of river and tidal conditions that control water depth through this section of the barge route. Specifically this assessment identifies the combination of river stage and tide required for operation of the shallow draft tug. It is assumed that a typical shallow draft tug requires continuous channel depth of at least 3½ ft (1 m) of water. :

A detailed discussion of the depth criteria and operational assumptions is also provided in the subsequent sections of this report.

1.1 Previous Work

A detailed hydrographic survey and hydrologic analysis for the area of interest was completed by Sandwell Inc. in 1995 for Redfern Resources. This excellent technical analysis provides the basis for this work. The current work represents an update of the previous assessment.



Study Area Map

Bathymetry of Lower Taku River

Redfern Resources Ltd.

Legend

- Waterbody
- Glacier
- Boundary
- Barge Landing Site

Scale: 1: 700,000

Kilometres: 0 5 10 20

Miles: 0 5 10 20

Projection: UTM Zone 8N, NAD 83
Grid / Interval: UTM Zone 8 / 10 Km

Prepared By:	JW	Reviewed By:	GS
Project Number:	Redfern	Date Issued:	July 2007

Gartner Lee

Figure Number: 1

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2. Methodology

2.1 Field Visit

Bathymetric information was collected during a 3-day field assessment completed between June 5th and June 7th, 2007. A local Taku River fisherman (David Parisienne), with over 20 years of experience on the Taku River, was hired as the boat operator. A 17-foot aluminium riverboat was used to navigate the river, which provided access into areas as shallow as one foot (0.3 m) deep.

The water depths were collected using a Sonarmite v2.0 Portable Bluetooth Echo Sounder, while location was collected using a Trimble GeoXT GPS unit. The resolution for the echo sounder is 0.025 m. The echo sounder was mounted on the transom of the boat (Photo 1) and was approximately 18 cm below the water's surface, flush with the bottom of the boat. (e.g., 0.18 m below water surface).

Photo 1. Echo Sounder Used to Conduct Survey

During the 3-day bathymetric survey, it was observed that the stage (i.e., river discharge) of the Taku River was rising steadily. To correct for changes in river stage as well as tidal effects, a Hobo Levelogger was installed to continuously track change in water levels. Automated measurements were collected at 15-minute intervals over the course of the survey. The levelogger was attached to a tall aluminium pole and was installed into the Taku River along the west bank approximately in the middle of the study area (shown on Figure 1) near the location referred to as the “Rock Pile”. Photo 2 provides an image of the level logger location.

Photo 2. Location of Levelogger near the Rock Pile (flagging)

2.2 Post-processing of Bathymetry Data

2.2.1 Control for River Stage and Tide

As mentioned, the Taku River was rising steadily throughout the survey period. To relate all of the surveyed points to a common datum, therefore, a correction for change in river stage and tidal effect was required. The levelogger provided a detailed account of water level changes, however the instrument malfunctioned during the last two days of the survey, during which time the highest river stage was recorded. In order to track changes in water levels during this period, a relationship between the levelogger data (specifically when it was operational during low tide periods) and the Taku River water survey gauge located upstream at Canyon Island (USGS 15041200), was constructed (Figure 2). This allowed all of the survey data to be corrected to a specific condition known as the “control stage” (i.e., during low tide conditions and the highest river stage discharge recorded during the study period). The “control stage”, period has been identified on Figure 2 by a red box and represents a river discharge of 2450 m^3/sec (86,600 cfs).

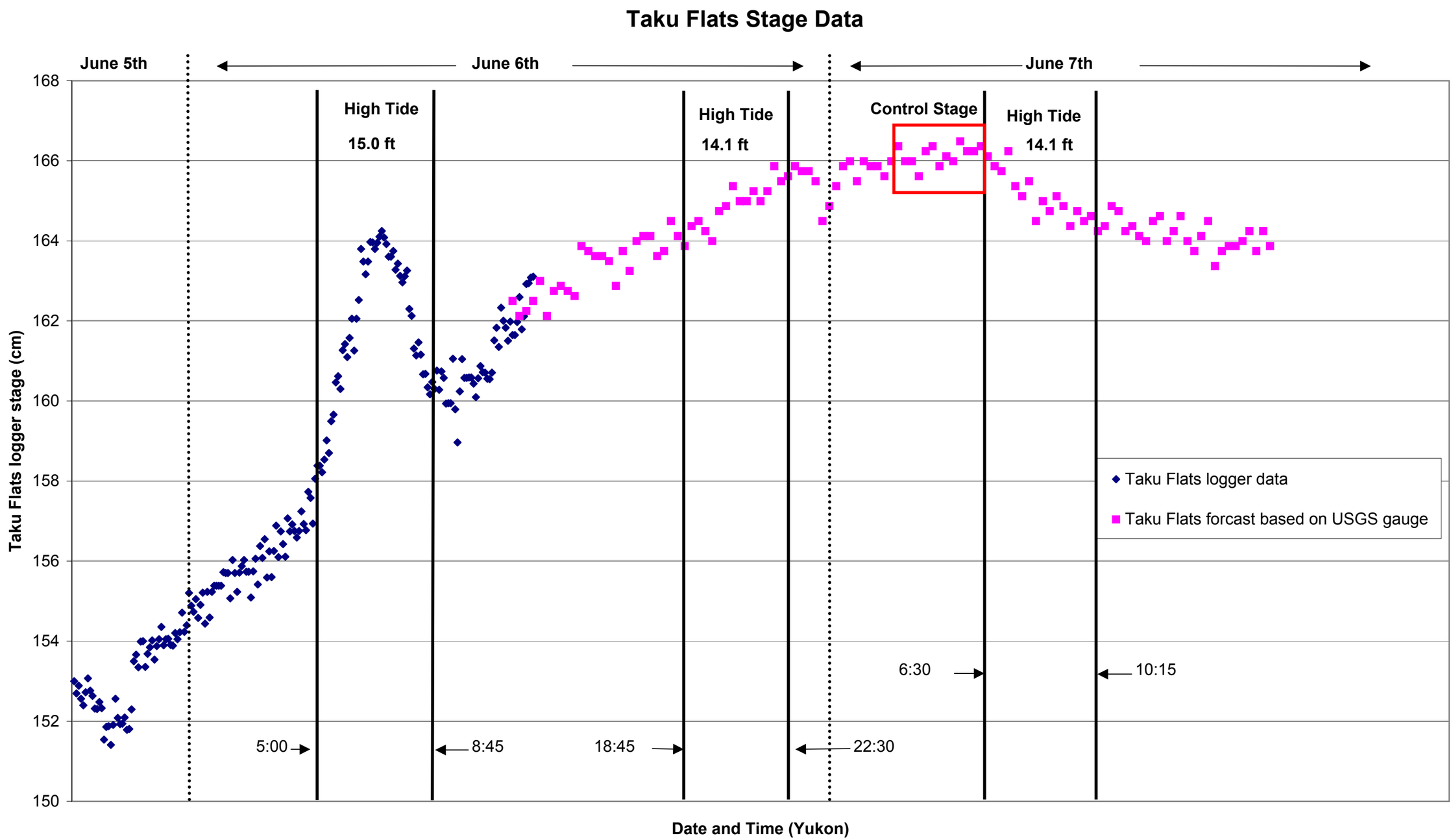

Figure 2: The levelogger and USGS gauge outlines the rise in river stage during the bathymetry survey. Note, the high tides were not recorded by USGS gauge/levelogger correlation (pink dots).

The data collected over the 3-day survey period was then broken down into 3-hr segments. The corresponding river stage (at low tide) for the same 3-hr period was then averaged and used to correct the measured water depths. As indicated by Figure 2, the river stage fluctuated 0.14 m over the survey period, recording a river discharge change from 2020 m^3/s (71,600 cfs) to 2450 m^3/s (86,600 cfs). Water depth observed over the survey period was corrected to a "control stage" water level.

2.2.2 Sandwell Report (1995) and Tidal Control

Sandwell[1] conducted a hydrological survey within the same study area in August of 1995. A copy of this report is provided in Appendix A. This detailed study developed water depth adjustments for various tidal scenarios in relation to river discharge (see Table 5.1 of Sandwell report). Sandwell (1995) also developed a stage-discharge relationship at three locations within the Taku sand flats:

1. Taku Lodge (upstream limit of study area);
2. Moss (near the "Rock Pile"); and
3. Taku Point. (downstream limit of study area).

Using the tide/river discharge relationships developed by Sandwell (1995), the bathymetric data collected during this study was adjusted to reflect "Sandwell" chart datum. Sandwell's chart datum is established at a river discharge of 500 m^3/s, and a mean low tide "0 ft", measured at Juneau, Alaska. A correction for all water depths depending on location (i.e., Taku Lodge, Moss, or Taku Point) was then calculated based on Sandwell's stage discharge relationship for the Lower Taku River (Figure 5.1, Sandwell 1995).

By way of example, the discharge during the "control stage" period (Figure 2) of this survey was 2,450 m^3/s (USGS 15041200), which corresponds to a river stage at low tide of 5.6 m at Moss (Figure 5.1, Sandwell, 1995). In relation to chart datum (i.e., low tide + river discharge 500 m^3/s), the depth at Moss Point is 4.5 m. Thus a correction factor of 1.1 m was subtracted from all measured depths in the vicinity of Station Moss to reduce the data from this survey to chart datum conditions. Correspondingly, a depth correction of 1.1 m (same as Station Moss) and 1.7 m was subtracted from the measured depths in the vicinity of Taku Point and Taku Lodge respectively. For locations between Moss Point, Taku Point and Taku Lodge, a liner extrapolation was applied across the reach of the river.

Once all the survey points had been reduced to chart datum, it was then possible to relate various river discharge levels and tidal conditions to the bathymetry data collected in this survey.

[1] *Sandwell (1995), Taku River Hydrographic Survey. Final Report. For Redfern Resources Ltd for the Tulsequah Chief Mine.*

2.3 Data Interpolation

Once observed data was corrected to a common water level (e.g., "control stage" of 2450 m^3/sec (86,600 cfs), the bathymetric data was corrected to continuous data (e.g., a raster grid) using ArcGis GRID. Gridded, or continuous data was then reduced to chart datum as described previously.

Once the chart datum grid was derived, a series of discharge/tide scenarios was developed by extracting from Sandwell's Table 5-1.

Once all data manipulation was completed, the gridded data was converted back to a point file and all points were than plotted overtop of the topographic base map. The data was then contoured by hand at 2-ft and 3-ft contour intervals. The resulting manually interpreted contour lines were then scanned, and digitized.

3. Discussion of Results

A series of water depth charts have been developed to represent a variety of stage/tide scenarios. Figures 3 to 6 represent these scenarios and show the extent of channels with between 2 and 3 feet, and >3 ft. (0.6 and 1.0 m, and >1.0m) of water within the study area. Generally, it is assumed that the air cushion barge skirts will drag across the sand flats infrequently with water depths greater than 2 ft. Furthermore the amphibious tractor requires somewhat less than 2 ft of water to operate aquatically.

3.1 Taku River Stage Scenarios

A total of four scenarios were chosen to illustrate the channel depths in relation to river discharge and tidal influence. These scenarios are presented as follows:

- Figure 3: A river discharge of 500 m^3/s and a 0 ft. tide, or mean lower low water (MLLW) (measured at Juneau, Alaska).
- Figure 4: A river discharge of 500 m^3/s and an 8 ft. tide, or mean water (MHW) (measured at Juneau, Alaska).
- Figure 5: A river discharge of 500 m^3/s at a "16 ft" or mean higher high water (MHHW) (measured at Juneau, Alaska).
- Figure 6: A river discharge of 700 m^3/s at a 0 ft. or mean lower low water (MLLW) (measured at Juneau, Alaska.)

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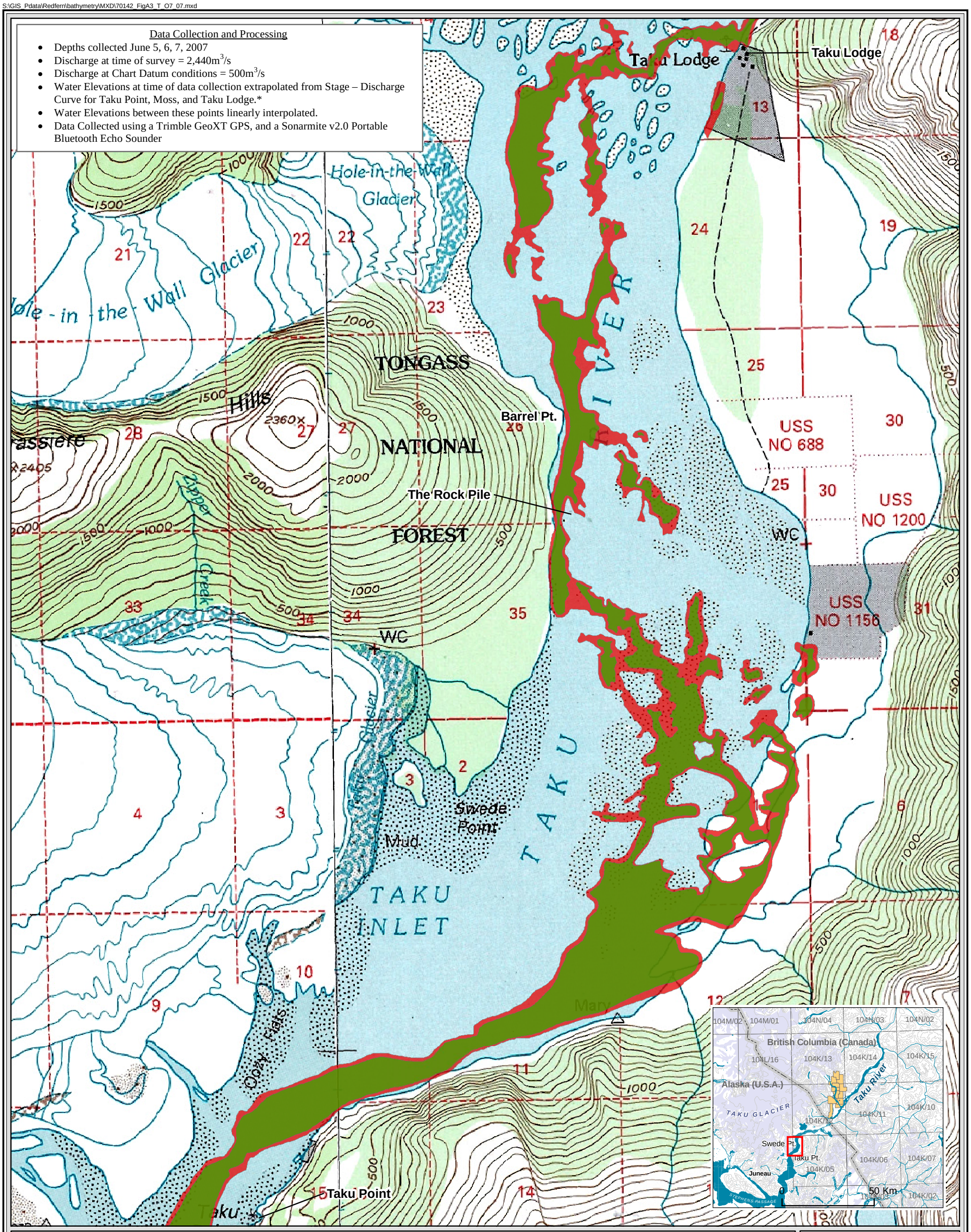

Map Sources/Notes:
Water Depth Measurements Collected on June 5-7/2007 by Gartner Lee Ltd. field staff.
*'Figure 5.1 Stage - Discharge Relationship for Lower Taku River' (Larson, M., Byres, R., 1995)
Topographic Images derived from Digital Raster Graphic (DRG) Images produced by the USGS.

Kilometres
0 0.25 0.5 1
0 0.25 0.5 1
Miles

1:30,000
UTM Zone 8N, NAD 83

Legend

- Areas with > 3 ft of water
- Areas with between 2 and 3 ft of water
- Areas with < 2 ft of water

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Reviewed By: FP
Date Issued: July 2007
Prepared By: JW
Project Number: 70142

Redfern Resources Ltd.

Bathymetry of Lower Taku River:

River Discharge 500m³/s and Mean Low Low "0 ft" Tide (MLLW)

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Figure 3
Version 1

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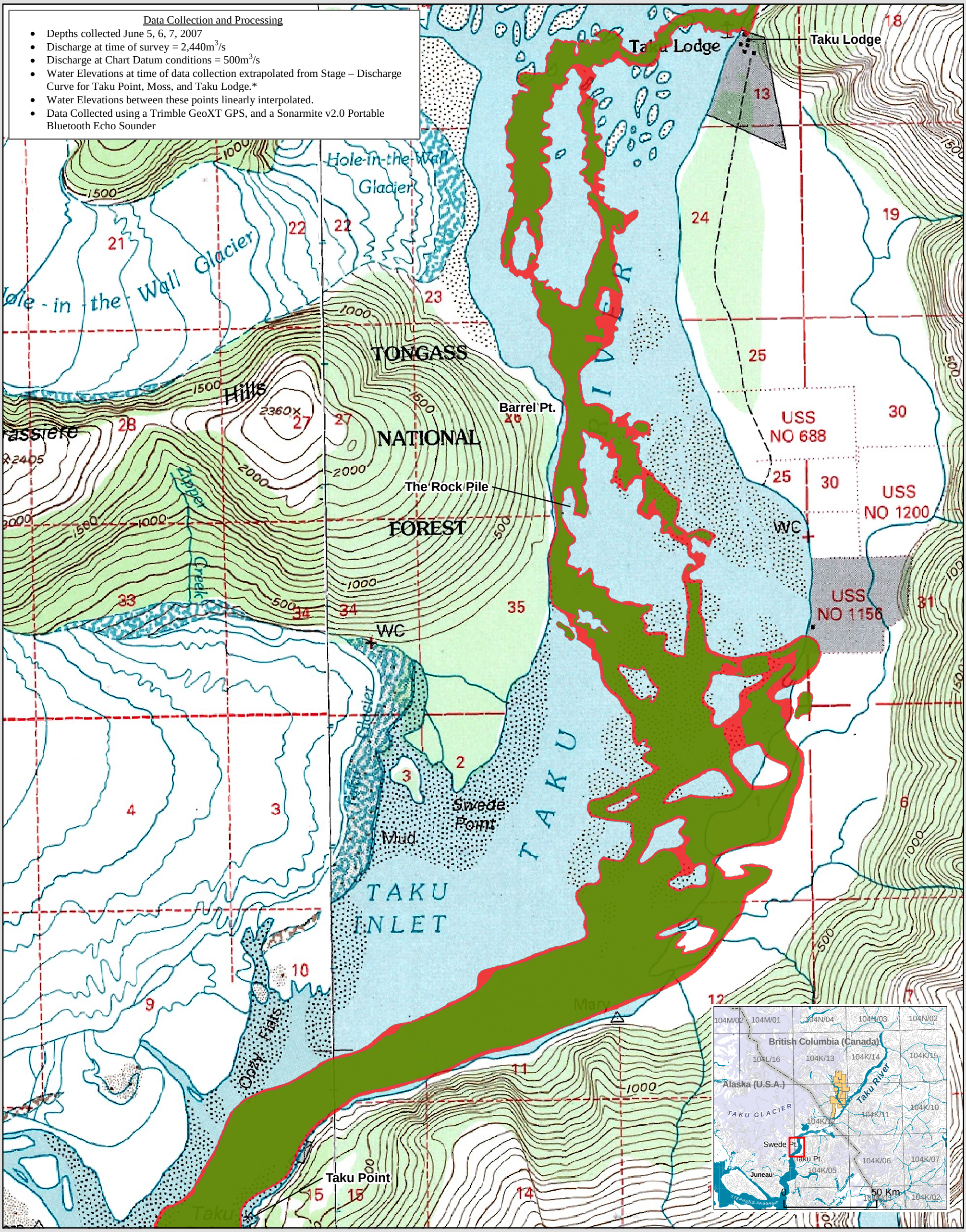

Map Sources/Notes:
Water Depth Measurements Collected on June 5-7/2007 by Gartner Lee Ltd. field staff.
*"Figure 5.1 Stage - Discharge Relationship for Lower Taku River" (Larson, M., Byres, R., 1995)
Topographic Images derived from Digital Raster Graphic (DRG) Images produced by the USGS.

Kilometres
0 0.25 0.5 1
0 0.25 0.5 1
Miles

1:30,000
UTM Zone 8N, NAD 83

Legend

- Areas with > 3 ft of water
- Areas with between 2 and 3 ft of water
- Areas with < 2 ft of water

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Reviewed By: FP
Date Issued: July 2007
Prepared By: JW
Project Number: 70142

Redfern Resources Ltd.

Bathymetry of Lower Taku River:

River Discharge
500m³/s
and Mean "8 ft" Tide
(MWL)

Gartner Lee

Figure 4
Version 1

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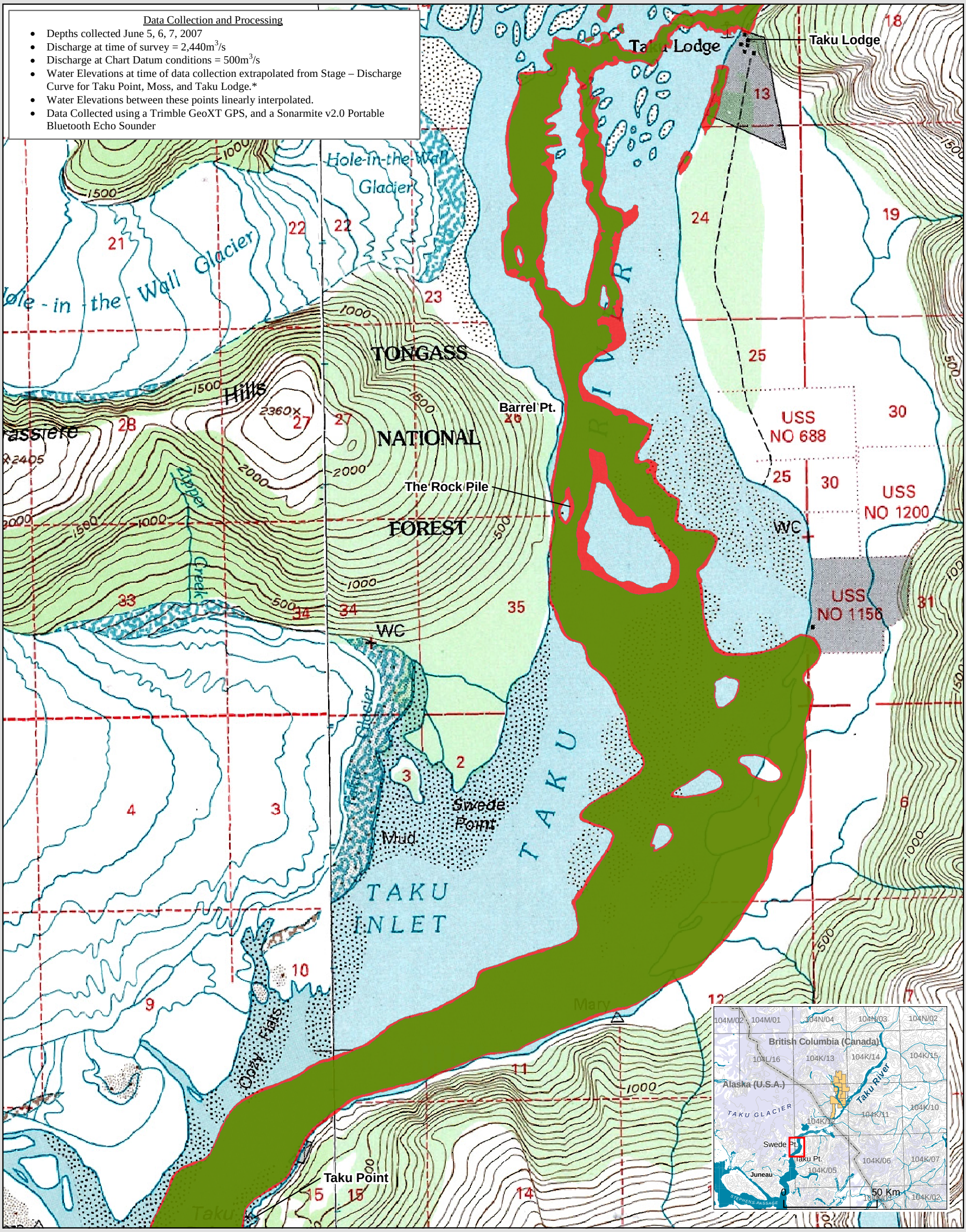

Map Sources/Notes:
Water Depth Measurements Collected on June 5-7/2007 by Gartner Lee Ltd. field staff.
*"Figure 5.1 Stage - Discharge Relationship for Lower Taku River" (Larson, M., Byres, R., 1995)
Topographic Images derived from Digital Raster Graphic (DRG) Images produced by the USGS.

N W E S

Kilometres
0 0.25 0.5 1
0 0.25 0.5 1
Miles

1:30,000
UTM Zone 8N, NAD 83

Legend

- Areas with > 3 ft of water
- Areas with between 2 and 3 ft of water
- Areas with < 2 ft of water

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Reviewed By: FP
Date Issued: July 2007
Prepared By: JW
Project Number: 70142

Redfern Resources Ltd.

Bathymetry of Lower Taku River:

River Discharge 500m³/s and Mean Higher High "16 ft" Tide (MHHW)

Gartner Lee

Figure 5
Version 1

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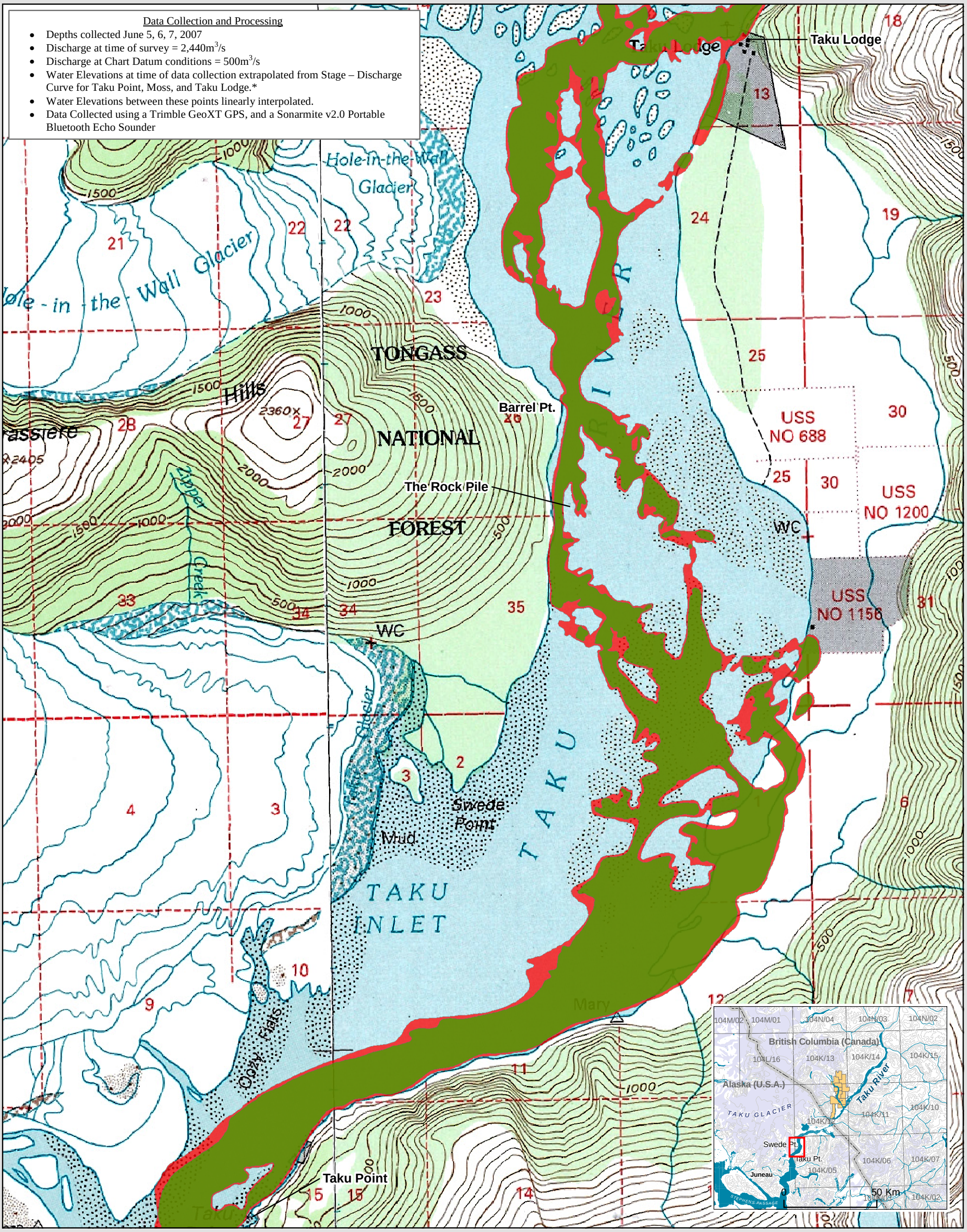

Data Collection and Processing

- Depths collected June 5, 6, 7, 2007
- Discharge at time of survey = 2,440m^3/s
- Discharge at Chart Datum conditions = 500m^3/s
- Water Elevations at time of data collection extrapolated from Stage – Discharge Curve for Taku Point, Moss, and Taku Lodge.*
- Water Elevations between these points linearly interpolated.
- Data Collected using a Trimble GeoXT GPS, and a Sonarmite v2.0 Portable Bluetooth Echo Sounder

Map Sources/Notes:
Water Depth Measurements Collected on June 5-7/2007 by Gartner Lee Ltd. field staff.
*'Figure 5.1 Stage - Discharge Relationship for Lower Taku River' (Larson, M., Byres, R., 1995)
Topographic Images derived from Digital Raster Graphic (DRG) Images produced by the USGS.

Kilometres: 0, 0.25, 0.5, 1
Miles: 0, 0.25, 0.5, 1

1:30,000
UTM Zone 8N, NAD 83

Legend

- Areas with > 3 ft of water
- Areas with between 2 and 3 ft of water
- Areas with < 2 ft of water

Redfern Resources Ltd.

Bathymetry of Lower Taku River:

Summer River Discharge 700m^3/s
and Mean Low Low "0 ft" Tide (MLLW)

Gartner Lee

Figure 6
Version 1

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Reviewed By:	FP	Prepared By:	JW
Date Issued:	July 2007	Project Number:	70142

In all of the figures listed above, the green areas represent water depths of three feet (1 m) or deeper whereas red areas represent water depths between two and three feet. The blue areas are less than two feet deep. Areas with water depths of three feet or more identify the channel where a conventional shallow draft tug could navigate, and where the ACB would not touch the bottom sediments of the channel.

3.2 Observations and Comments

Several observations can be made from this analysis:

1. A discharge of 500 m^3/s was identified by Sandwell (1994) as a normal low water level in the Taku River during the aquatic season (e.g., May to Oct.). Average summer discharge is approximately 700 m^3/s (mid May to Sept.).
2. When the Taku River discharge is at 500 m^3/sec and there is a low tide (MLLW or 0' tide at Juneau) (Figure 3), one section of river at the downstream end of "Hole in the Wall Glacier" is shallower than 2 feet. Under such conditions, a shallow draft tug could not successfully navigate this segment of river. There is a second "pinch point" near Taku Lodge where the channel of adequate depth is very narrow and likely discontinuous during lower flows.
3. These two shallow sections of the channel near Taku Lodge and downstream of Hole in the Wall Glacier correspond to the constraint areas identified in Sandwell, 1995. Furthermore, the location of the channel identified in the current study correlates broadly with that mapped in 1995. This suggests that the river channels through this area are generally more stable than local/ conventional knowledge has suggested, at least over the past decade or so.
4. When the Taku River discharge is at 500 m^3/s and the tide is "Mean" (8' tide at Juneau) (Figure 4), the same problem area at the downstream end of "Hole the Wall Glacier" is present, albeit for a shorter distance. The water depth through this section of the channel is between two and three feet deep and suggests that a tide higher than mean tide (e.g., 8' tide) is needed to navigate this section of the river.
5. When the Taku River discharge is at 500 m^3/s and the tide is "high" (16' tide at Juneau) (Figure 5), a continuous route of 3-ft and/or deeper is present. During these conditions, a shallow draft tug can successfully navigate this section at higher tides.
6. Once the river discharge reaches 700 m^3/s or greater (Figure 6), which is the mean river discharge during the summer months, it is possible to navigate vessels through the study area regardless of tidal conditions.

3.3 Barging Season Using a Conventional Shallow Draft Tug

Figure 7 represents a hydrograph of the Taku River. The solid black line indicates the mean flow, the whiskers indicate maximum and minimum monthly average flows, and the red and blue dashed lines indicate monthly average high and low flows (e.g., one standard deviation), respectively.

As discussed, the results of this analysis indicate that a shallow draft tug can successfully navigate the river once the discharge reaches 700 m^3/s or greater, regardless of tidal conditions. Shallow draft tugs can also navigate at flows of 500 m^3/s combined with tides in excess of 8 ft. Therefore based on the mean flow of the Taku River hydrograph (i.e., 700 m^3/s, Figure 7), the shallow draft tug could generally operate from the middle of May to the third week in August (a period of approximately 14 weeks), without relying on higher tides. Barging using a shallow draft tug could also operate an additional 6 weeks during higher tides when the Taku River discharge falls below 700 m^3/s (to a minimum of 500 m^3/s). At other times of the year, the amphitrac, operating primarily aquatically, on wheels, and/or on ice, is required.

3.4 Conclusion

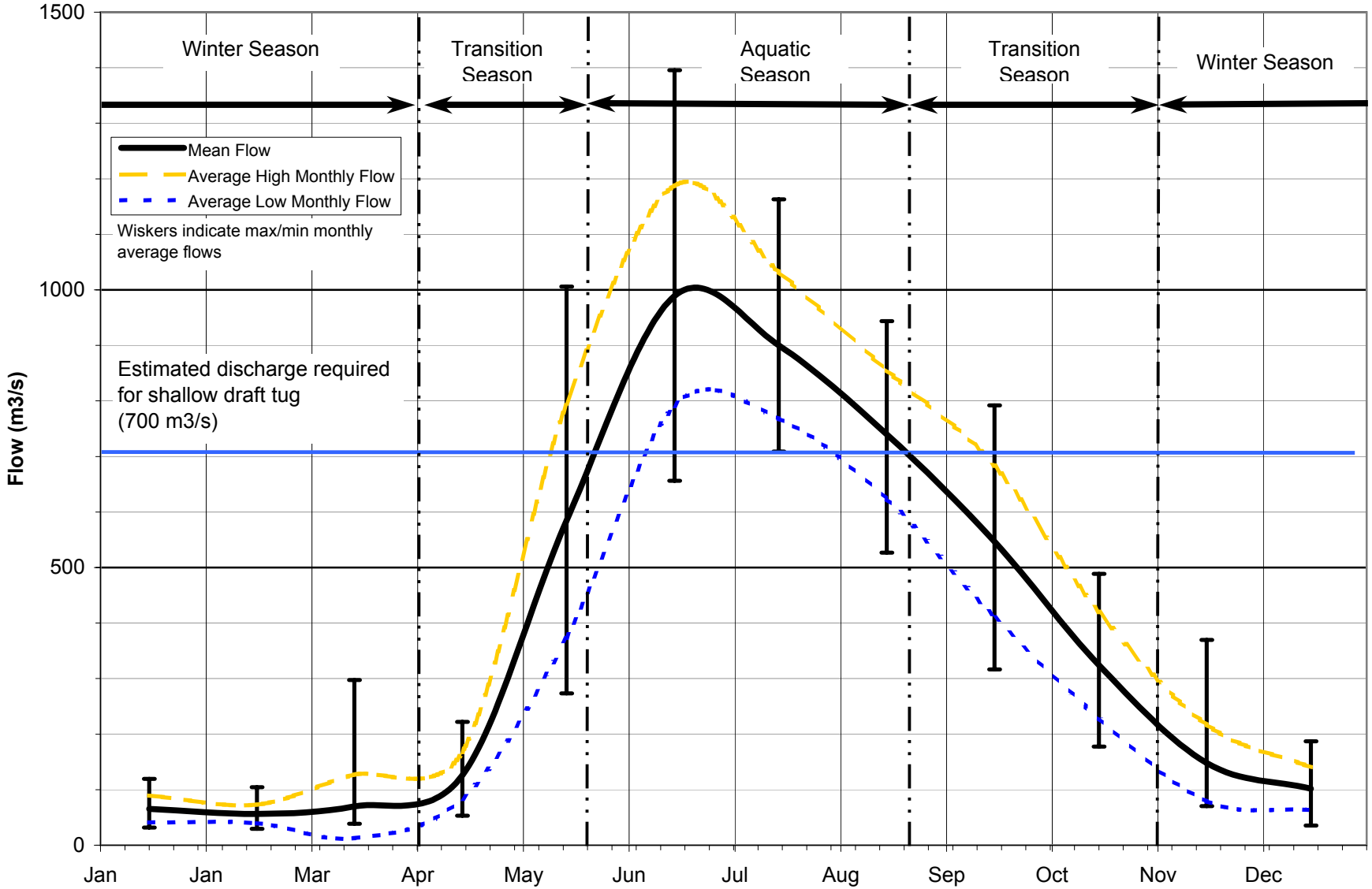
The previous bathymetric analysis identifies the River stage and tide conditions required for the transit through the Lower Taku River sand flats area with a typical shallow draft tug (e.g., requiring a continuous channel with 3 ft. (1.0 m) or more of water). Specifically, the analysis indicates that a continuous channel with >3 ft. of water exists:

1. when flows in the Taku River are >700 m^3/s; or
2. when flows in the Taku River are >500 m^3/s and there is at least an 8 ft. tide (e.g., mean tide).

Outside of this set of environmental conditions, use of the amphibious tractor will be required to tow the Air Cushion Barge through the shallowest sections of the channel in this part of the river.

Figure 7. Taku River Hydograph at Canyon Island

1986 - 2006



70142_Figure_7_Taku_hydrograph.xls

4. Limitations

This report was prepared for the exclusive use of Redfern Resources Ltd. The report, which specifically includes all tables and figures, is based on data and information collected during the investigations conducted by Gartner Lee Limited, and is based solely on the conditions of the site at the time of the investigation, supplemented by historical information and data obtained by Gartner Lee Limited, as described in this report.

The investigations and designs described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibility of such third parties. Gartner Lee Limited accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on the information contained in this report.

Should you have any questions regarding this report, or require further information, please contact the undersigned.

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Fluvial Geomorphologist

Report Prepared By:

Jonathan Kerr, M.Sc., P.Geo.
Hydrogeologist

Report Reviewed By:

Forest Pearson, P.Eng.
Geological Engineer

PROJECT 113673
December 12, 1995

REDFERN RESOURCES LTD.

TULSEQUAH CHIEF MINE

TAKU RIVER HYDROGRAPHIC SURVEY

FINAL REPORT

Prepared by: Max Larson, P. Eng.

Ron Byres, P. Eng.

Reviewed by: John Readshaw, P. Eng.

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Appendix A

"Taku River Hydrographic Survey", Sandwell Inc., 1995

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1. SUMMARY AND CONCLUSIONS

A hydrographic survey of the lower Taku River between Taku Point and Taku Lodge was carried out in July and August 1995. The purpose of the survey was to establish the minimum water depths available for navigation and to determine whether dredging would be required to allow the Tulsequah Chief mine to operate using barges to transport mineral concentrates and supplies.

Most of the soundings were carried out in August 1995 during a period when the river discharge was approximately 500 m^3/s, the lowest on record[1] for that month. The influence of the tides was removed to obtain the "near worst case" (i.e. lowest) water depths available for navigation. Since it is possible for the flow in future years to be even less than it was in 1995, the available water depths in extremely dry years could be even less than indicated in this report.

The results of the survey show that under the "near worst case" conditions, there are several shoal areas in the river where the depths are less than the 1.5 metres required to navigate a barge of 500-800 deadweight tonnes. In some cases the channel is completely blocked by these shoals, and barge navigation would not be possible unless the discharge were greater or the tides were used to boost the water depths. This means that if the ability to navigate in summer months on a continuous basis was required, the shoal areas would need to be dredged to provide a minimum depth of 1.5 metres. It is not known how long such a dredged channel might remain stable before either shifting or filling in with sediment. Based on qualitative experience obtained in the river in 1994 and 1995, it is believed that the bed is highly mobile and that significant shifting of the channels occurs. It is likely that regular maintenance dredging would be required to keep a dredged channel open, although it is not clear how frequently this would be required.

The water level data recorded as part of the hydrographic survey allow estimates to be made of water depths under any particular combination of tide and river discharge. The effects of the tide are most pronounced in the lower-most reaches of the river and gradually die out upstream. At Taku Lodge the tidal influence is still present but is of negligible benefit for navigation purposes. On the other hand variations in river discharge have a significant effect throughout the entire study reach.

Based on analysis of the water gauge data, it is estimated that during dry years (such as 1995), tidal influence is not sufficient to provide a navigable depth over the governing shoals except on very high spring tides. These spring tides occur only for a few days each month, which is considered to be too infrequent for practical navigation operations. For example, when using the lowest recorded Mean Monthly flows to represent a dry year, navigation over the governing shoals (without dredging) would only be possible for about 16 days during the summer.

In more "normal" years when the discharge is near average levels of 800-1100 m^3/s, navigation would be possible for a longer period. Using the averages of the recorded Mean Monthly flows to represent a "normal" year, it was calculated that navigation over the critical shoals would be possible for about 90 days. It is

[1] Canyon Island permanent gauge station records 1988-1995

important to note however that in any particular year the discharge from month to month might vary considerably, which would affect the calculated number of navigable days.

Since the feasibility of navigation on the river would be controlled more by "dry" conditions than by average conditions, it is concluded that the use of barges to transport concentrate and supplies to the Tulsequah Chief mine would require dredging during some years. Even during years of higher flow, occasional spot dredging may be required to prevent the channels from shifting or filling with sediment. It is noted that the amount of sediment brought downstream during high flow years is greater than that during dry years. The effects of such an influx of sediment cannot at present be predicted, but may well have the effect of increasing the overall amount and severity of shoals compared to those shown in this report.

2. INTRODUCTION

This report summarizes the results of a hydrographic survey undertaken on the lower Taku River during July and August, 1995 (Drawing 113673-8-S01). The work was done at the request of Redfern Resources and Rescan Engineering Ltd. as part of their development of the Tulsequah Chief Mine in northern British Columbia. The survey was one of the recommendations of a previous report[1] which examined the feasibility of using barges to transport concentrates and supplies for the mine.

Previous operations of the mine during the 1950's used small barges to export ore in shipments of about 200-300 tonnes. In 1981 and 1994, barges were used to deliver supplies and equipment up to the Taku-Tulsequah confluence. The success of these shipments has shown that barge navigation is possible under some conditions of tide and river discharge. This precedent led Redfern to propose using barges to export mine concentrates and to import fuel and other supplies.

The Marine Transportation Options report concluded that navigation using barges of 500-800 tonnes capacity during the summer months would be possible. However, the presence of numerous shoals in the lower portions of the river made it uncertain whether the planned shipping volumes could be achieved without dredging. A lack of data relating to water depths, tidal influence, and river flow levels made it impossible to assess for certain whether dredging would be required. This was the key uncertainty that affected the overall economics of river transportation. If navigation were not independent of these effects, it would be necessary either to dredge portions of the river or wait for a suitable tide "window" to get over the shallows.

To address these uncertainties, a hydrographic survey of the lower Taku was undertaken. The work was intended to assess the potential for barge navigation during the high summer runoff period. The survey was restricted to 13 kilometres of the river between Taku Point and Taku Lodge, as it is this portion of the river that poses the greatest navigational difficulties. The main goals of the survey were to:

- establish the existence, if any, of a "deep water" channel through the lower reaches of the river;
- identify the water depths available during the high summer runoff period;
- establish whether dredging is required to allow navigation at all stages of the tide for the range of likely discharges;
- attempt to identify whether any significant shoaling, erosion, or channel shifting takes place during the summer months.

Chapter 3 of this report describes the survey methodology followed to obtain the raw bathymetric survey and water level data required to characterize the river. Chapter 4 contains the analysis of the acquired data

[1] Sandwell, 1995a. Tulseqhah Chief Mine - Marine Transportation Options. Report prepared for Redfern Resources Ltd., February 23/95.

and the derived results, and Chapter 5 contains a discussion of the survey results in relation to the goals listed above.

3. SURVEY METHODOLOGY

Sandwell was requested to develop a scope of work for Juneau-based Alaska Land Surveyors Co. (ALS), and to provide field assistance as required to oversee the survey work.

The survey methodology was designed to address the immediate needs of charting the river depths, as well as to allow for the creation of long-term water level prediction tools. The prediction tools could be used to predict navigability on a day-by-day basis if regular barge operations were introduced in the future. The survey goals listed in Chapter 1 were to be met by the surveyor through the completion of the following tasks:

- establishment of permanent horizontal and vertical survey control stations in the vicinity of Taku Point, Swede Point, Taku Lodge and upstream;
- establishment of temporary water level recording stations at control stations listed above at which at least one month of water levels data were to be recorded;
- undertaking a hydrographic survey in August, 1995 with a high vertical positioning accuracy;
- construction of a hydrographic chart based on water depths below datum (as is conventional in tidal waters);
- undertaking a second hydrographic survey in September, 1995 for comparison with the summer survey to identify areas in which the channel has shifted due to infilling or erosion.

3.1 Equipment

The presence of numerous shallow bars throughout the survey area required that the survey be undertaken from a flat bottom river boat of minimal draft. Positioning was provided using a Differential Geographic Positioning System (DGPS) capable of yielding the following theoretical accuracies:

horizontal	±1.0m moving (for hydrographic survey)
	±0.01m stationary (for establishing onshore reference stations)
vertical	±0.05m moving
	±0.02m stationary

The system employed a radio telemetric link suitable for coverage of the 13 km of river requiring survey.

The positioning system used an associated software and hardware system to record positions digitally at a rate of 1 per second. The system also had navigational capabilities so that the boat position relative to the survey area could be determined at all times to ensure that survey lines could be planned and duplicated if required.

Depths were measured using a narrow beam echo sounder which recorded data in both paper and digital format. A paper record was taken as backup to the digital record and to assist in examination of unusual bathymetry. Depths were measured at a frequency of 1 Hertz and recorded to the nearest decimeter.

Elevations of the river bed were computed by subtracting the water depth data from the elevation of the water surface. The water surface elevation was measured at the beginning and end of each survey line using a "total station" electronic theodolite.

3.2 Datums

Horizontal survey data were originally acquired in decimal feet with respect to NAD 1927 and were converted to UTM coordinates referenced to horizontal datum NAD 83. Elevations are referenced to chart datum at Taku Point as defined by the US Coast and Geodetic Survey control point data for Taku Point, Taku Inlet at latitude 58° 24.0'N, longitude 134° 00.9'W (1937). This control point is located at an elevation of 11.00 m above the official USCGS chart datum (see Appendix B for survey monument descriptions).

3.3 Control points

Permanent horizontal and vertical control points were established at the locations indicated on Drawing -S02. The permanent control stations allow future surveys to be quickly undertaken and tied in to the previous work to identify any changes over time.

Horizontal positioning of the permanent stations is considered accurate to ±0.01 m or better and reported to a precision of two decimal places (i.e., nearest centimetre). Some of the station locations on Drawing -S02 appear to be situated in the river rather than on land. This effect is due to digitization of the shoreline, which was taken from published 1:63,360 scale topographic maps. The maps were based on air photos from 1948 and 1951, and may not accurately represent the present shoreline or be referenced to a horizontal datum with the same precision as GPS positions. This has no effect on the accuracy of station coordinates or sounding locations shown on the drawing. Shoal areas can be quickly re-located or monitored in the future since the soundings are tied into permanent fixed control stations.

Where necessary, the position of the "approximate shoreline location" in Drawings -S03 to -S12 was adjusted slightly to agree with the survey data. These corrections were minor (on the order of several metres at most) and in no way affect the conclusions of the study.

Vertical positioning of the control points is accurate to ±0.02 m and reported to a precision of two decimal places.

3.4 Hydrographic Survey

The hydrographic survey provided coverage of the main channel as identified in a reconnaissance survey of the lower Taku River during July and August. The area surveyed is shown in Drawing -S02, and was surveyed in detail on August 14-16, 1995.

The survey consisted of a coarse preliminary grid to map the overall area and identify the main channel(s) for more detailed coverage. The goal was to produce a continuous longitudinal survey line down the centre of the main channel with additional lines on 25 m offsets either side or as the existing channel width allowed. Channel cross sections were to be taken at approximately 250 m intervals over the survey area, with additional lines added in regions where water depths are less than 0.5 m or in locations where the main channel is not

clearly identifiable. The actual survey line locations varied somewhat due to practical considerations including the difficulty of visually identifying the channel in the heavily silt-laden river. Special attention was given to areas with features of navigational interest such as snags, boulders, etc.

3.5 Water Level Recording

In order to correct the soundings for the variable influence of the tides and fluctuations in river discharge, a series of four water levels gauges were deployed at locations close to the permanent control stations shown on Drawings -S01 and -S02. Each gauge was capable of resolving the water level to ±0.01 m. The recorders were programmed to record one-minute average total pressures at five minute intervals over the deployment period which is summarized in Table 3.1.

Table 3.1: Water Level Data - Period of Record

Station Name	Unit Number	Orifice Elevation (m) (USCGS datum)	First Record (local)	Last Record (local)
"Taku Point"	*293*	0.580	July 21 16:15	August 30 19:05
"Moss"	*335*	3.109	July 21 15:45	August 30 18:15
"Taku Lodge" (original)	*162*	3.871	July 21 12:10	July 28
"Taku Lodge" (re-deployed)	*162*	2.293[1]	July 28	August 30 17:40
"Island"	*292*	5.883	July 21 12:10	August 30 17:10

[1] Estimated based on change in recorded water levels relative to Station "Island" gauge before and after instrument was disturbed.

Immediately after deployment of the gauges, the water surface elevation was recorded and referenced to the permanent control station using a theodolite.

To provide a check on recorded water levels at each station, water surface elevations were measured adjacent to each of the stations at least once per day during the survey periods.

4 SURVEY RESULTS

4.1 River Discharge Records

River discharge is measured upstream of the study area by the U.S. Geological Survey at a permanent station at Canyon Island. Figure 4.1 shows the variation of flow conditions before, during, and after the bathymetric survey. Flow conditions during the survey (August 14 to 16) were relatively steady with flow rates between 500 and 600 m^3 /s. The period of record also captured a large several-day flow event that peaked at 2320 m^3/s on 26 July 1995. This event allowed a direct comparison to be made between relative water level changes at the different gauge sites, an important part of predicting water levels for periods other than when the survey was carried out. A similar but smaller flow event was recorded in September during the second period of water level recorder deployment, but was not analyzed for this report.

Figure 4.2 compares the 1995 water level data from the Canyon Island station to similar records collected in previous years. It can be seen that 1995 represents a relatively dry year, with the mean monthly flow rate for June and August being the lowest of the entire 7-year record. Discharge data from July are also lower than average although there are drier years on record. While the mean monthly flow for July was lower than normal, the peak daily flow on 26 July was the largest such peak on record. Spikes in the flow commonly occur in summer months and raise the numerical mean flow rate somewhat higher than the "effective" flow rate which can be relied upon for navigation. This effect is discussed further in Section 5.

The annual variation in water level at Canyon Island is greater than it is at points further downstream. As the river valley broadens, the water spreads out over a wider, shallower area, and annual fluctuations in discharge have a diminishing effect on water levels; this is discussed further in Section 4.2 below.

4.2 Water Level Recorders

Pressure data from the four water level recorders were converted to water depth data after first correcting for the effects of atmospheric pressure variations and water density. Using measurements of water surface elevation with respect to Taku Point datum (1937), the water depths were converted to the surface elevation data shown in Figures 4.3 to 4.5. Also shown for comparison are the measured tides at Juneau, which are considered representative of the deep portions of Taku Inlet downstream of Taku Point.

The data show that the three downstream gauge stations are influenced by the tides, with the amount of influence decreasing upstream. The water levels tend to closely follow the peaks of the tides, but the troughs of the semi-diurnal cycles are truncated or "clipped" due to the minimum water levels governed by the freshwater flow component of the estuary. This includes the records from the Taku Point station, which until now have been considered fully tidal by the U.S. Coast and Geodetic Survey.

Predicted tides for Taku Point are provided in annual tide tables published by the American National Oceanic and Atmospheric Administration (NOAA), and suggest that the tides are very similar to those at Juneau, with only minor corrections required. In fact, the data collected this year at Taku Point show that most of the lower half of the tide cycle is truncated. This suggests that a substantial level of sedimentation - at least 3 metres - has taken place at Taku Point since the "official" tide parameters were established in 1937.

The peaks of the tidal curves are also asymmetrical, with the tides rising faster than they fall. Similar effects have been observed in the Fraser River and are attributed to two causes [Thomson, 1981]:

- the speed of the tidal wave increases with water depth, speeding the upstream propagation of the tide; and,
- the effects of bottom friction are more pronounced in shallow water, retarding the seaward retreat of the water.

These patterns are consistent with previous Taku River data reported in the earlier Marine Transportation Options report, and show that for each location along the river, there is a different minimum tide height required to affect water levels at the location. Below this specific height, the river levels are unaffected by tides and are affected only by changes in runoff volumes.

A prominent feature in the water gauge data is the sharp "spike" in water levels coincident with the July 26 flow event described above. ALS reports that the spike corresponds to a period of heavy rainfall in the upper river valley, although the spike may also be related to the glacial lake outburst phenomenon which commonly occurs on the Tulsequah River during summer months. Regardless of the cause, the steeply rising and falling portions of the record allow a direct comparison to be made of the relative water level changes at the various gauge sites. Since the river discharge at Canyon Island is also known during this period, the spike allows an estimate to be made of the relationship between discharge at Canyon Island and water levels downstream, based on the assumption of pseudo-steady uniform flow conditions.

This knowledge of downstream water levels is crucial in allowing the results of the survey to be extended beyond the time of the actual survey to other times of the year when the discharge is at different levels.

4.3 Sounding Data

Sounding data were collected during campaigns in August and September. This report is based on the August survey as these were the only reduced data available at the time of writing. Data were provided by ALS in the form of two files: one containing a survey coordinate listing and associated raw measured depths, and a second file containing the same coordinate listing and river bed elevations. The river bed elevations were determined through subtraction of the measured water depths from the instantaneous water surface elevation measured at the start of each survey line.

4.4 Survey Data Reduction

Recorded pressure data include both water and atmospheric pressure components. Recorded pressures were converted to water depths after subtracting the atmospheric pressure component as measured at hourly intervals at Juneau Airport. The effects of varying water density were also estimated by assuming that the water density varied from brackish to fresh between Taku Point and Taku Lodge. Although no actual measurements of water density were made, the maximum error introduced by this assumption would be on the order of 2% of the depth, or about 40 mm in water of 2 metres depth. Water depths at each gauge were converted to water level relative to the datum at Taku Point through application of the elevations listed in Table 3.1.

Selection of an appropriate chart datum for the survey required consideration of both tidal fluctuations and freshwater discharge. Chart datum is loosely defined as "the elevation below which the water level rarely falls". Different agencies use a different interpretation of "rarely" and hence different chart datum elevations. In U.S. tidal waters the datum is defined by the mean low tide.

For the Taku River the situation is more complicated because the river bed is sloping and the effects of the tide gradually die out moving upstream. Since the bottom portion of the tide curves are truncated, the low water level is defined by discharge, not tide. Although the lowest river flows occur during winter, it was assumed that only the summer months were of interest for navigation purposes, and so development of a chart datum for the river was based on summer discharge levels. River discharge during August 1995 was relatively constant, and was the lowest mean monthly flow level in the 7-year record. It was therefore considered reasonable and somewhat conservative to use the average August 1995 discharge as the base condition for establishing a "summer" chart datum on the river. During drier years when the flow is even less than during August 1995, water depths would fall below this definition of chart datum.

A combination of mean tides and typical August (1995) discharge levels occurred on August 26 and August 30. Lower low waters during these periods were averaged at each of the gauge locations, and a sloping datum was defined linking the gauge locations "Taku Point", "Moss", and "Taku Lodge". Table 4.1 indicates the elevation of project chart datum at the three stations with respect to the US Coast and Geodetic Survey datum at Taku Point (1937).

Table 4.1: Elevation of Chart Datum at Gauge Locations

Location	Project Chart Datum Elevation (m above USCGS 1937 datum)
Station "Taku Point"	2.5
Station "Moss"	4.4
Station "Taku Lodge"	5.9

As discussed in Section 4.2, the area around Taku Point has experienced substantial sedimentation since the last official hydrographic charts were prepared. The "official" US Coast and Geodetic Survey chart datum at Taku Point suggests that in 1937 mean low water was 2.5 metres below the present mean low water level. This implies that the actual mouth of the river (ie where the sloping river datum meets the horizontal ocean datum) is a considerable distance downstream from Taku Point. With the high sediment load carried in the Taku River, this downstream migration of the river mouth will continue indefinitely.

The current American hydrographic charts downstream of Taku Point were based on soundings made in the 1960's and do not accurately represent the present depths. This is noted on the charts with the warning, *"Shoaling to bare at MLLW (mean lower low water) has been reported throughout the northern part of Taku Inlet. Mariners should exercise caution."* The area downstream of Taku Point was not included in the scope of the 1995 survey, however ALS reported some difficulty in negotiating their way through the shoals well to the south of Taku Point. Additional surveying work would be required to identify whether there are any critical shoals downstream of Taku Point which would restrict navigation at low tide.

The elevation of chart datum increases 3.4 m between Taku Point and Taku Lodge. Because sloping datums are not practical for presentation in chart form, the river was segmented into 35 contiguous reaches, each with a horizontal chart datum definition that is 0.1 m above the adjacent downstream reach.

The river bed elevation survey data acquired by ALS were spatially filtered to determine which reach definition was applicable to each survey data point. The correct chart datum adjustment was applied to each survey point and a survey field sheet referenced to chart datums was created (Drawing -S02). The field sheet was contoured by hand to indicate those regions where a navigable depth of 1.5 m would be present at mean low tide when discharge is approximately 500 m^3 /s . The result is a "near worst case" chart of water depths along the stretch of river from Taku Point to Taku Lodge. As discussed above, the chart is not a true "worst case" since it is possible in very dry years for summertime discharge to remain continuously below that discharge used to establish chart datum.

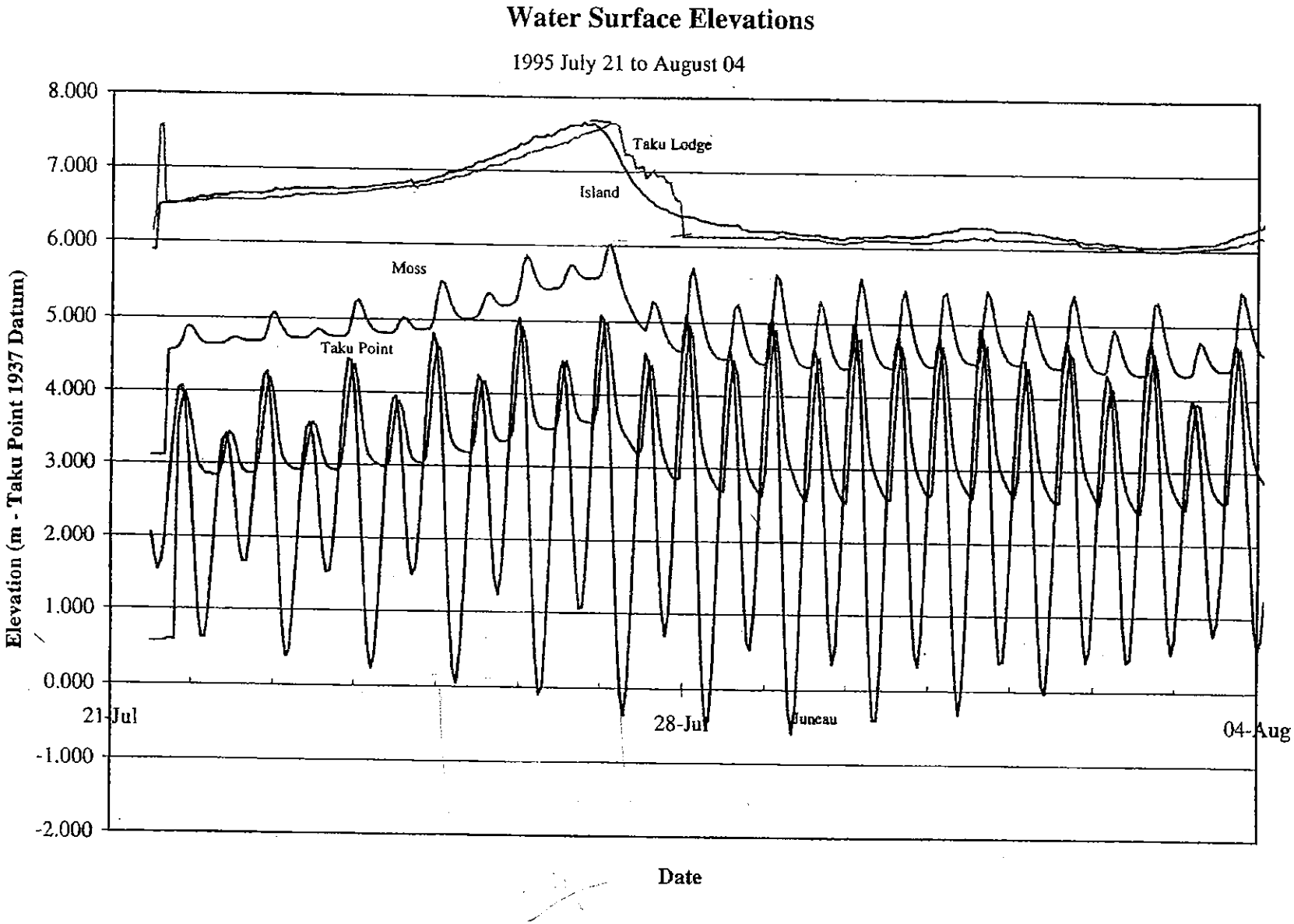

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Figure 4.3

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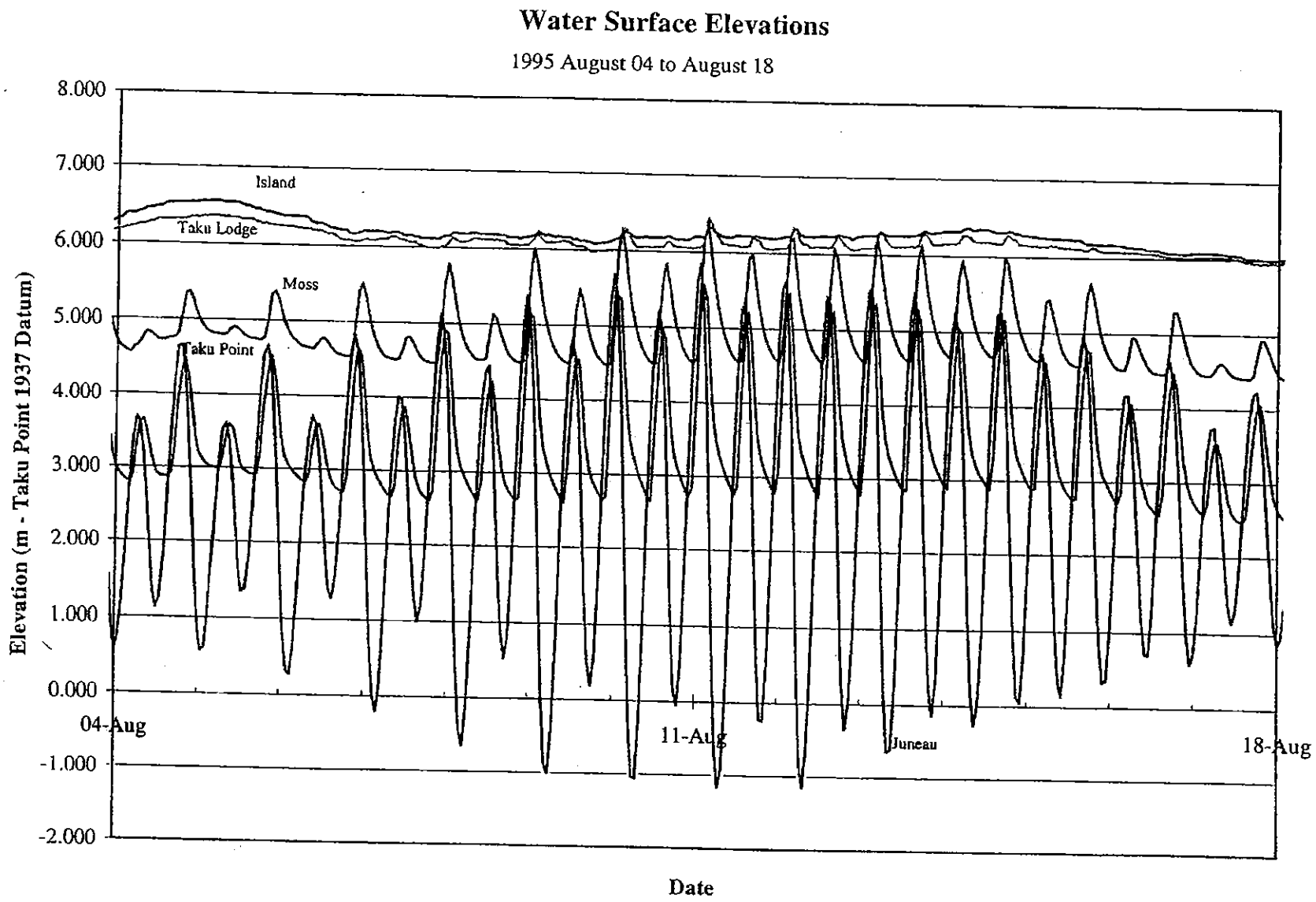

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Figure 4.4

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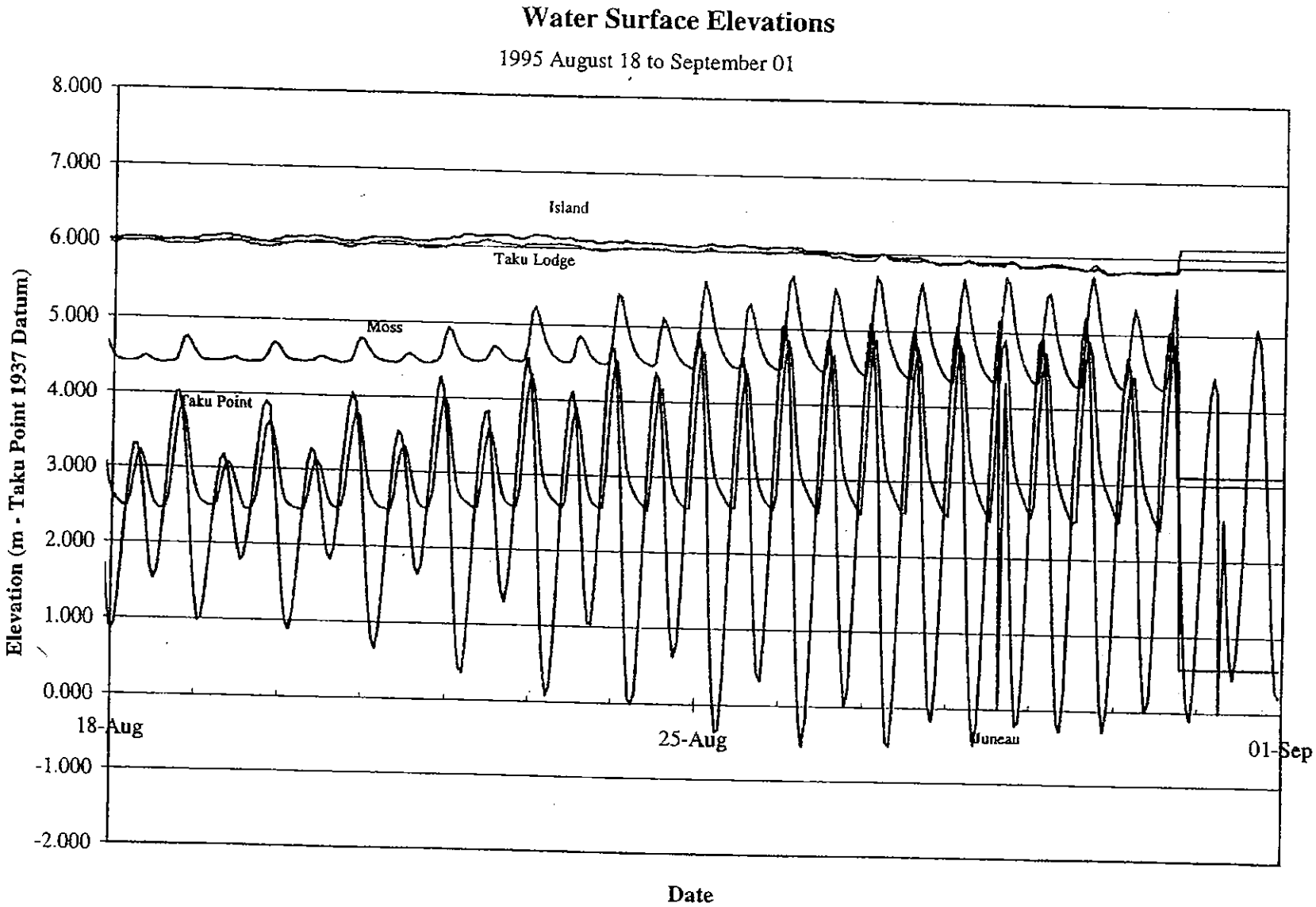

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Figure 4.5

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5. IMPLICATIONS ON NAVIGABILITY

5.1 Navigation at Low Tide / Low Flow

The sounding data included in Appendix A represent conditions without tidal influence and during a period when river discharge was the lowest level on record for summer months. These data can be considered to be the "near worst case", although it is possible that during some months or years the flow could be even less and water depths would be less than those indicated.

The shaded areas in Drawings -S02 to -S12 represent the areas less than 1.5 m deep at the time of survey. This depth was identified in the previous Marine Transportation Options study as the minimum practical draft for a 500-800 tonne river barge. The drawings show that under the "near worst case" conditions, there does *not* appear to be a continuously navigable channel from Taku Point to Taku Lodge. The channel appears to be completely blocked in several locations (eg. Drawings S03, S04, S07). Furthermore, the sounding coverage in some areas is too sparse to rule out the presence of even more shoals than those actually identified by the soundings. Drawing -S09 illustrates this point, where a different interpretation of the data would show an additional channel blockage. (Conversely, Drawing -S07 shows how it is possible that some of the shaded areas may actually have a deeper channel which was missed by the survey boat. This possibility is considered remote however, as over two weeks of reconnaissance time was spent mapping the "main" channels prior to the detailed soundings being collected.)

Even if a continuous channel did exist, it is doubtful whether the channel would be stable enough to be relied upon to provide continuous navigability. ALS noted that the channels seemed to shift around from one day to the next, especially after the large sediment influx and bed movements associated with heavy rains. ALS had considerable difficulty negotiating the area in their small, 150 mm-draft river boat, and the operator of a large barge with less manoeuvrability would be expected to have much more difficulty, even if the channel were clearly marked with closely-spaced buoys.

Since the sounding data do not show a continuous channel under these low flow conditions, it can be concluded that continuous barge navigation during low tide/low flow conditions is probably not feasible. Shipping mine concentrates and supplies by barge would rely upon either :

- a navigable channel being dredged through the shallow areas and maintained as required with either channel training works or periodic maintenance dredging; or
- specific "windows" of higher tide and/or river discharge conditions to raise water levels to the minimum depths required. Navigation could not be done "at will", but would be restricted to these windows.

The first option, namely dredging a navigable channel, is technically feasible but would likely face a number of restrictions from the various regulatory bodies. It is not known at this time how often maintenance dredging would be required to keep a channel open, but based on our personal experience in the river to date it is likely that the channel would require at least one and possibly several dredging campaigns each season.

The second option, using the effects of tide and discharge to boost water levels, is discussed in Section 5.2 below.

5.2 Navigation using Tidal/Freshet Assist

The effect of tides at the various water level recording stations was inferred earlier from Figures 4.3 to 4.5; the effect of discharge was isolated from these figures and is presented in Figure 5.1. The derived adjustment factors are listed in Table 5.1.

Table 5.1 Water Depth Adjustments for Tidal Influence and Discharge in the Lower Taku River
A - Station "Taku Point" B - Station "Moss" C - Station "Taku Lodge"

Tidal Conditions at Juneau, AK	Tidal Heights (m) for Specified Discharge at Canyon Island					
	500 m³/s			1000 m³/s		
	A	B	C	A	B	C
Mean HHW	2.4	1.3	0.1	2.9	1.8	1.0
MWL	1.2	0.6	0.0	1.7	1.1	0.9
Mean LLW	0.0	0.0	0.0	0.5	0.5	0.9

Use of the data in Table 5.1 is illustrated by the following example:

If the river discharge of interest were 500 m³/s and the tide at Juneau was near mean higher high water (HHW), then the plotted water depths in the vicinity of Taku Point would be increased by approximately 2.4 metres. Conversely, in the vicinity of Taku Lodge, the water depths would increase only 0.1 metres from those plotted. If the discharge increased to 1000 m³/s, then at mean high tide the plotted depths would increase by 2.9m and 1.0m at Taku Point and Taku Lodge respectively.

Selection of the appropriate discharge level in Table 5.1 may be obtained from the mean monthly discharge data plotted in Figure 4.2. Mean monthly discharge typically reaches an average of approximately 800-1100 m³/s in the months of June, July and August. The maximum daily flow rates for the river usually occur in July or August and have reached over 2400 m³/s in the past. These higher flows are short duration "spikes" probably associated with rainstorms or glacial lake outburst events on the Tulsequah. For navigation purposes it is more appropriate to consider the longer-duration mean monthly flow rate as shown in Figure 4.2. As discussed earlier in Section 4, it is important to note that the spikes raise the overall mean monthly flow rates above the "effective" flow rate which can be used for navigation. Therefore it should be kept in mind that the mean monthly flows plotted in Figure 4.2 are slightly higher than the amount of water actually available for navigation. For example, the mean monthly flow for July 1995 was 877 m³/s, but if the effect of the spike is removed the "effective" mean drops about 10% to 800 m³/s.

The shoal areas which block the navigation channel on Drawings -S03 and -S04 have water depths ranging from about 0.9 m to 1.3 m. The downstream shoal (Drawing -S07) is considered less critical since the constricting area is smaller and the depths are somewhat greater (1.2-1.4 m). In addition, the downstream shoal benefits more often from tidal effects than the upstream areas, which are close to Taku Lodge. The

upstream shoals shown in Drawings -S03 and -S04 are therefore considered to be the "governing" areas which restrict the overall navigability on the lower Taku River.

Using the stage-discharge curves in Figure 5.1, along with typical summer tidal data and the historical records of river discharge, an estimate was made of how frequently the governing shoals would have a minimum water depth of 1.5 metres. For this analysis, it was assumed that an additional 0.6 metres of water would be required to provide enough depth .

Two flow levels were considered. The lowest recorded Mean Monthly Discharge of the respective months was used as "near worst case" scenario (although for the reasons discussed above, it is possible for some years to have even less water). Similarly, the average Mean Monthly Discharge was used to represent "average" conditions. In each case the effect of tides was added to the base flow level, and the total amount of time the water depths were greater than 1.5 metres was calculated. The assessment was based on a 24 hour day, i.e. the navigable windows were not restricted to daylight hours only. This simplifying assumption has negligible effect on the results since the tidal effects near Taku Lodge are very small. The results of the analysis are shown in Table 5.2 below.

Table 5.2. Navigable Periods Near Taku Lodge (without dredging)

Month	Lowest Mean Monthly Discharge (m^3/s)	% Availability for Navigation	Average Mean Monthly Discharge (m^3/s)	% Availability for Navigation
June	656	4.6	1097	100
July	747	47.5	966	100
August	527	0	800	91.5
September	317	0	584	0.8
All Months	Total number of navigable hours	386	Total number of navigable hours	2150
	Equivalent days	16.1	Equivalent days	89.6

This result shows that without dredging, the critical areas downstream of Taku Lodge would be navigable for only about 16 days during years with low discharge, and less than 90 days during years with average discharge. Comparing the figures for July above, it appears that the critical discharge threshold is in the range of 800 - 900 m^3/s. Above this level, the shoal areas are always navigable, while below this threshold the effects of tides must be used to provide sufficient depth. The availability drops off rapidly at lower discharges because the tides do not have a large effect near Taku Lodge.

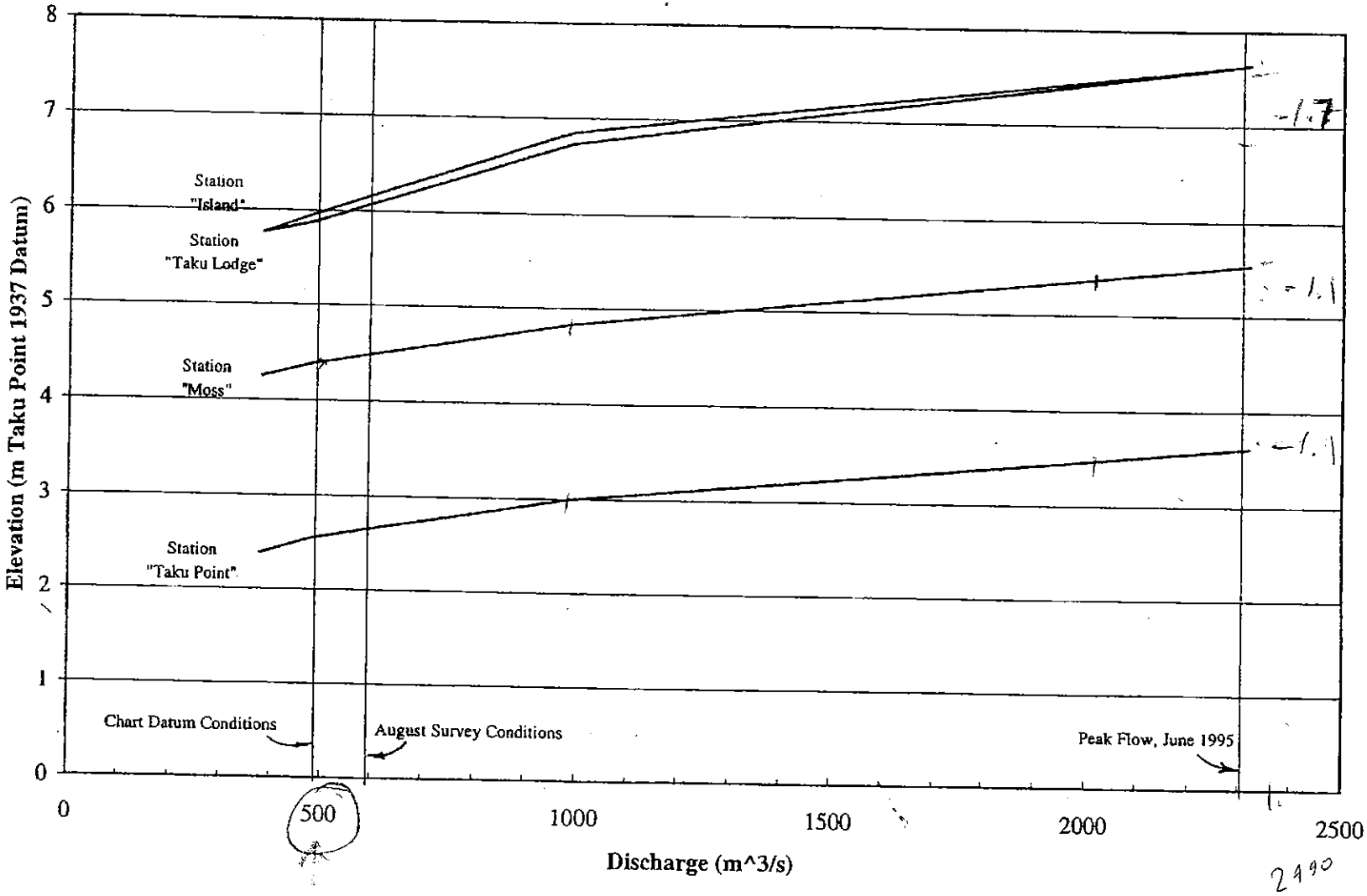
It should be noted that this analysis is for the particular shoals shown on Drawings -S03 and -S04, which were the governing areas at the time the survey was carried out. Natural changes in the river bed may alter the

depths over these shoals or create new shoals elsewhere, which would result in different values for the percentage availability figures shown.

The 90-day window discussed above falls somewhat short of the 100-day window used in previous reports to assess the viability of barge navigation. During years with higher than average discharge, the 100 day period may well be available without requiring dredging. However, given the variation in flow rates from year to year and the inability to accurately predict discharge in advance, this possibility should not be relied upon for long term operations. It is therefore recommended that development of the Tulsequah Chief mine be based on the assumption that dredging would be required during at least some years in order to allow the necessary volumes of barge traffic to navigate through the lower reaches of the Taku River.

Stage - Discharge Relationship

Lower Taku River



\\113673\technical\flows\QVSZ.XLS Chart

Figure 5.1

12/11/95 17:42

6. REFERENCES

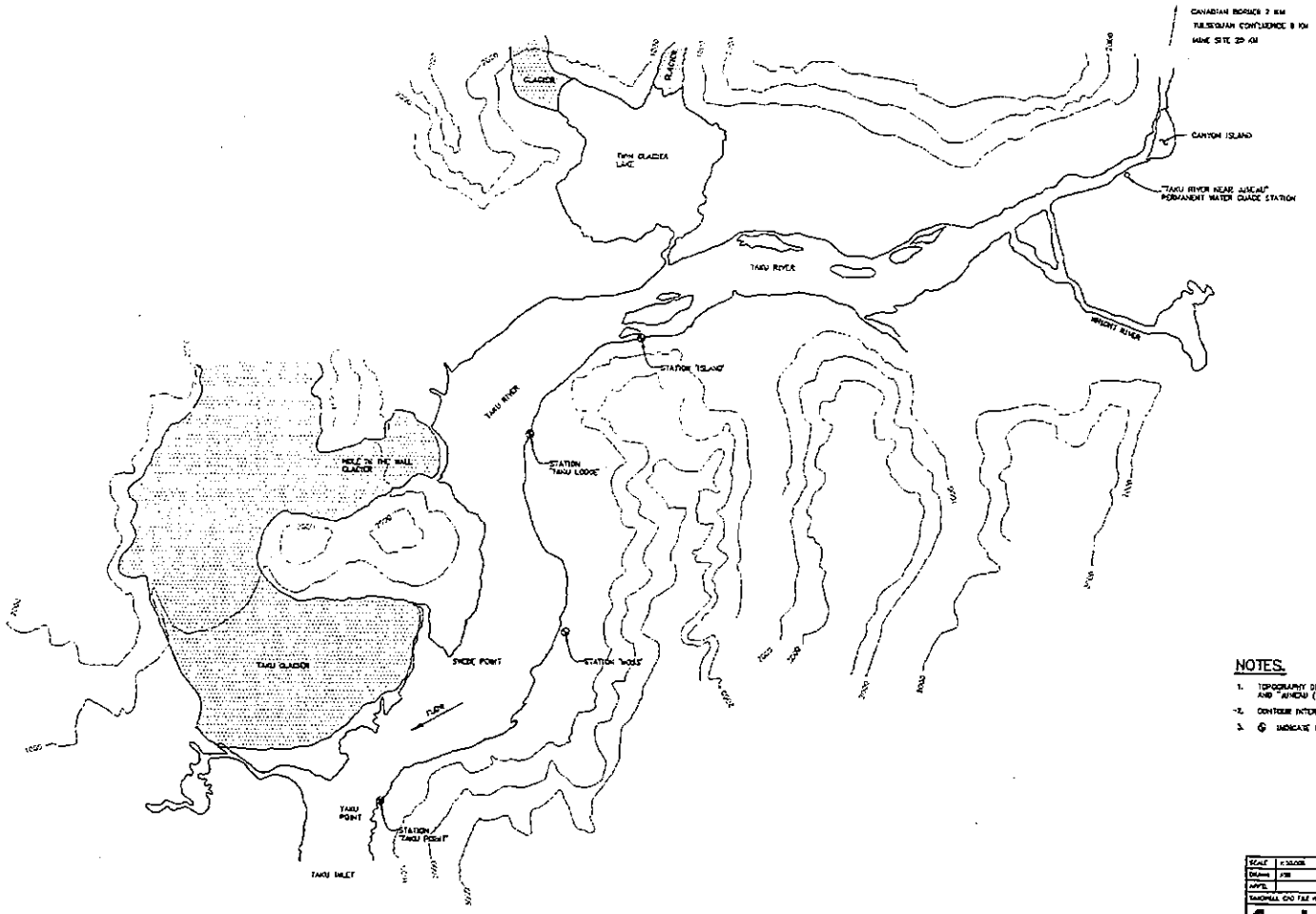
Alaska Land Survey Co., 1995. Taku River Field Survey. In progress.

Sandwell, 1995a. Tulseqhah Chief Mine - Marine Transportation Options. Report prepared for Redfern Resources Ltd., February 23, 1995.

Thomson, R.E., 1981. Oceanography of the British Columbia Coast. Canadian Special Publication, Fisheries and Aquatic Science 56: 291 p.

APPENDIX A

AUGUST, 1995 SURVEY DRAWINGS



NOTES.

1. TOPOGRAPHY DIGITIZED FROM USGS TOPOGRAPHIC MAPS "TAKU RIVER (B-4)" AND "JUNEAU (B-1)" DATED 1951 (MINOR REVISIONS 1971).
2. CONTOUR INTERVAL IS 1000 FEET.
3. ⊕ INDICATE WATER LEVEL RECORDER MONUMENT LOCATIONS.

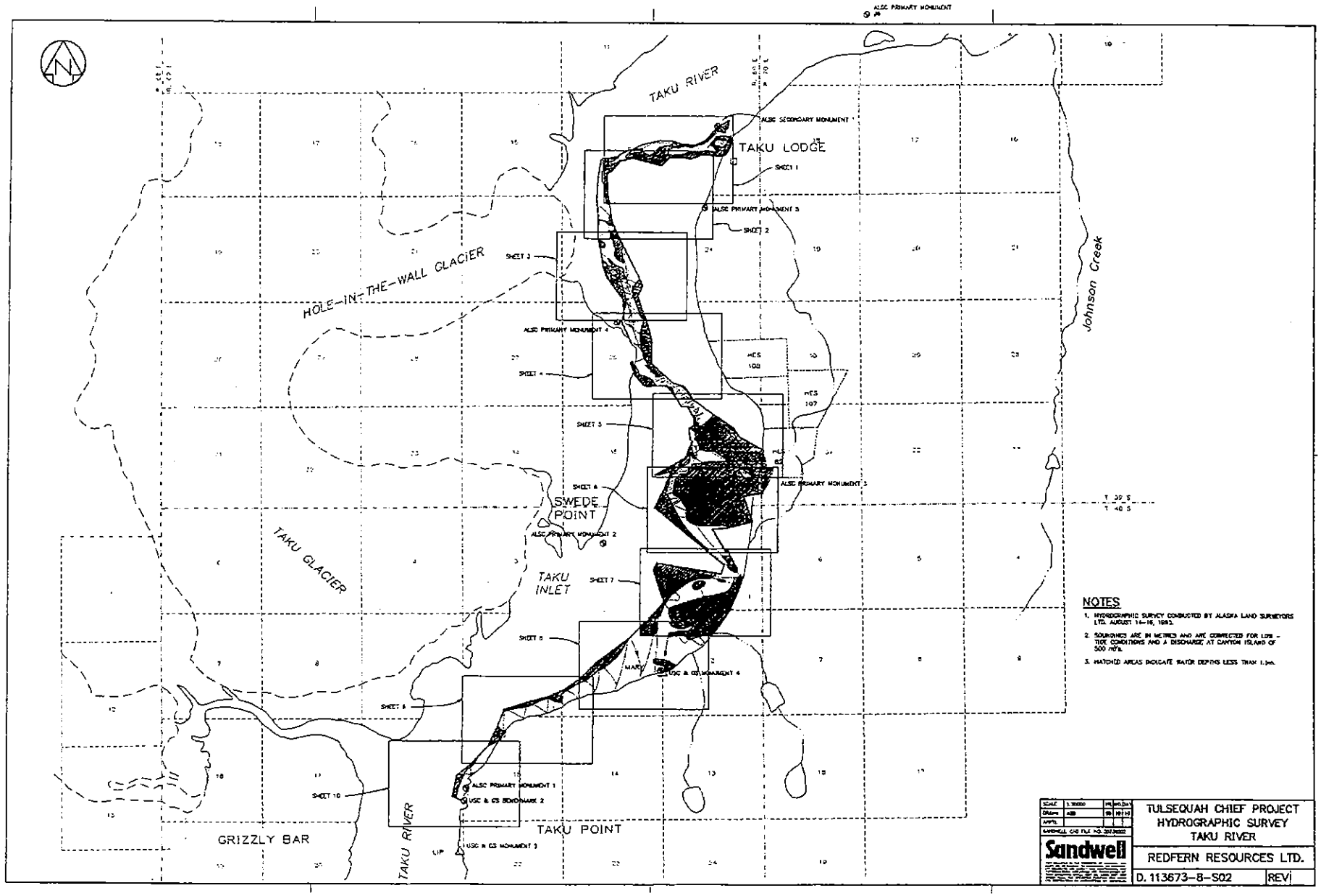
SCALE	1:50,000			
DRAWN	JSB			
APPR.				
SANDWELL CAD FILE NO. 3673.DWG				

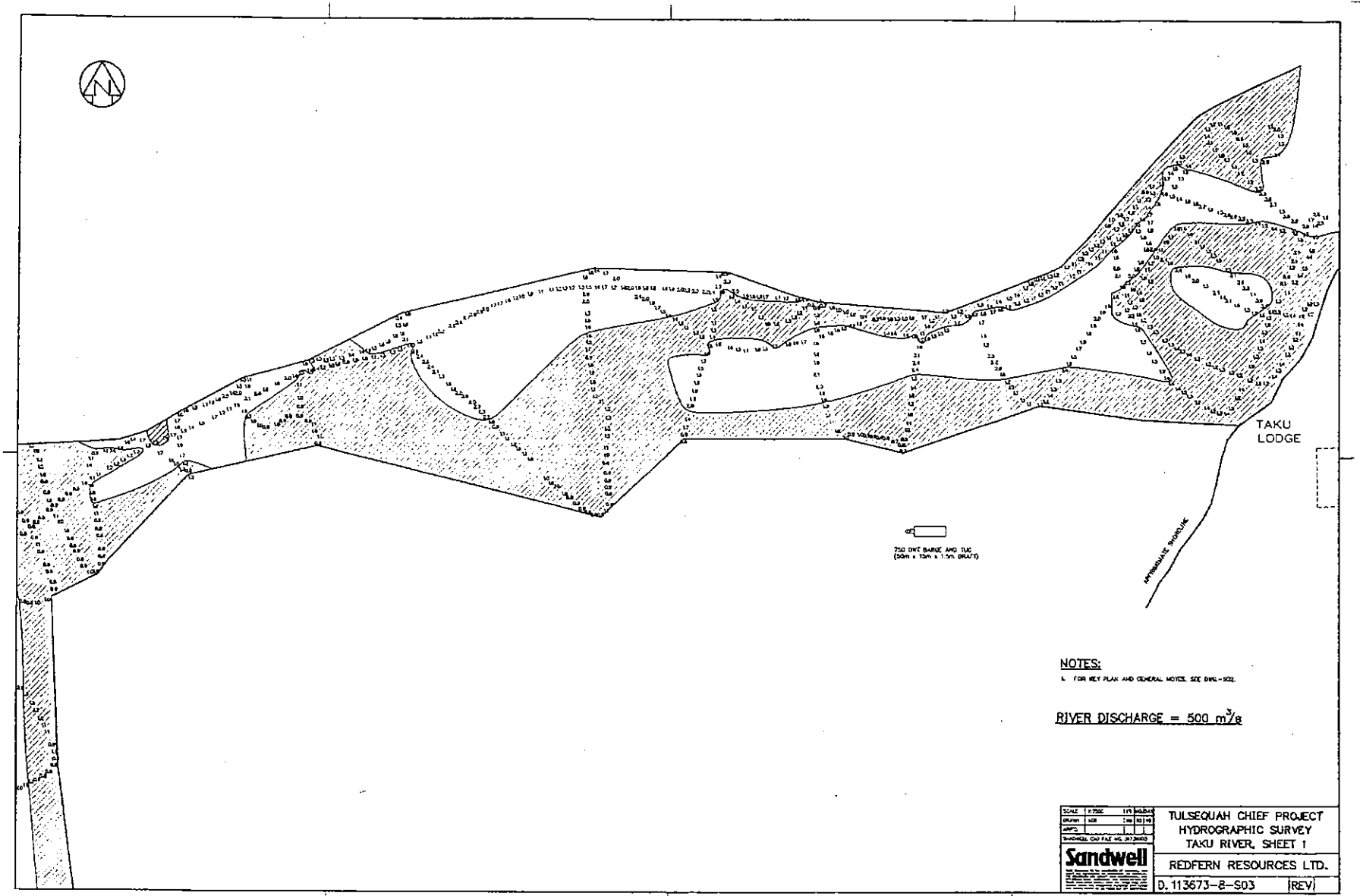
Sandwell

TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER – LOCATION PLAN

REDFERN RESOURCES LTD.

D. 113673-8-S01 REV


TAKU RIVER
TAKU LODGE
ALSC SECONDARY MONUMENT 1
ALSC PRIMARY MONUMENT 5
SHEET 1
SHEET 2
SHEET 3
SHEET 4
SHEET 5
SHEET 6
SHEET 7
SHEET 8
SHEET 9
SHEET 10
HOLE-IN-THE-WALL GLACIER
ALSC PRIMARY MONUMENT 4
ALSC PRIMARY MONUMENT 3
ALSC PRIMARY MONUMENT 2
ALSC PRIMARY MONUMENT 1
USC & GS MONUMENT 4
USC & GS BENCHMARK 2
USC & GS MONUMENT 3
SWEDE POINT
TAKU INLET
TAKU GLACIER
TAKU POINT
GRIZZLY BAR
TAKU RIVER
Johnson Creek
HES 100
HES 107
MARY
T 39 S
T 40 S
NOTES
1. HYDROGRAPHIC SURVEY CONDUCTED BY ALASKA LAND SURVEYORS LTD. AUGUST 14-16, 1993.
2. SOUNDINGS ARE IN METRES AND ARE CORRECTED FOR LOW - TIDE CONDITIONS AND A DISCHARGE AT CANYON ISLAND OF 500 m³/s.
3. HATCHED AREAS INDICATE WATER DEPTHS LESS THAN 1.5m.
Sandwell
TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER
REDFERN RESOURCES LTD.
D. 113673-8-S02
REV



NOTES:

1. FOR KEY PLAN AND GENERAL NOTES SEE DWG.-002.

RIVER DISCHARGE = 500 m^3/s

SCALE	1:7500		
DRAWN	MJB		
APPD			
SHORELINE COTTAGE NO. 3173000			

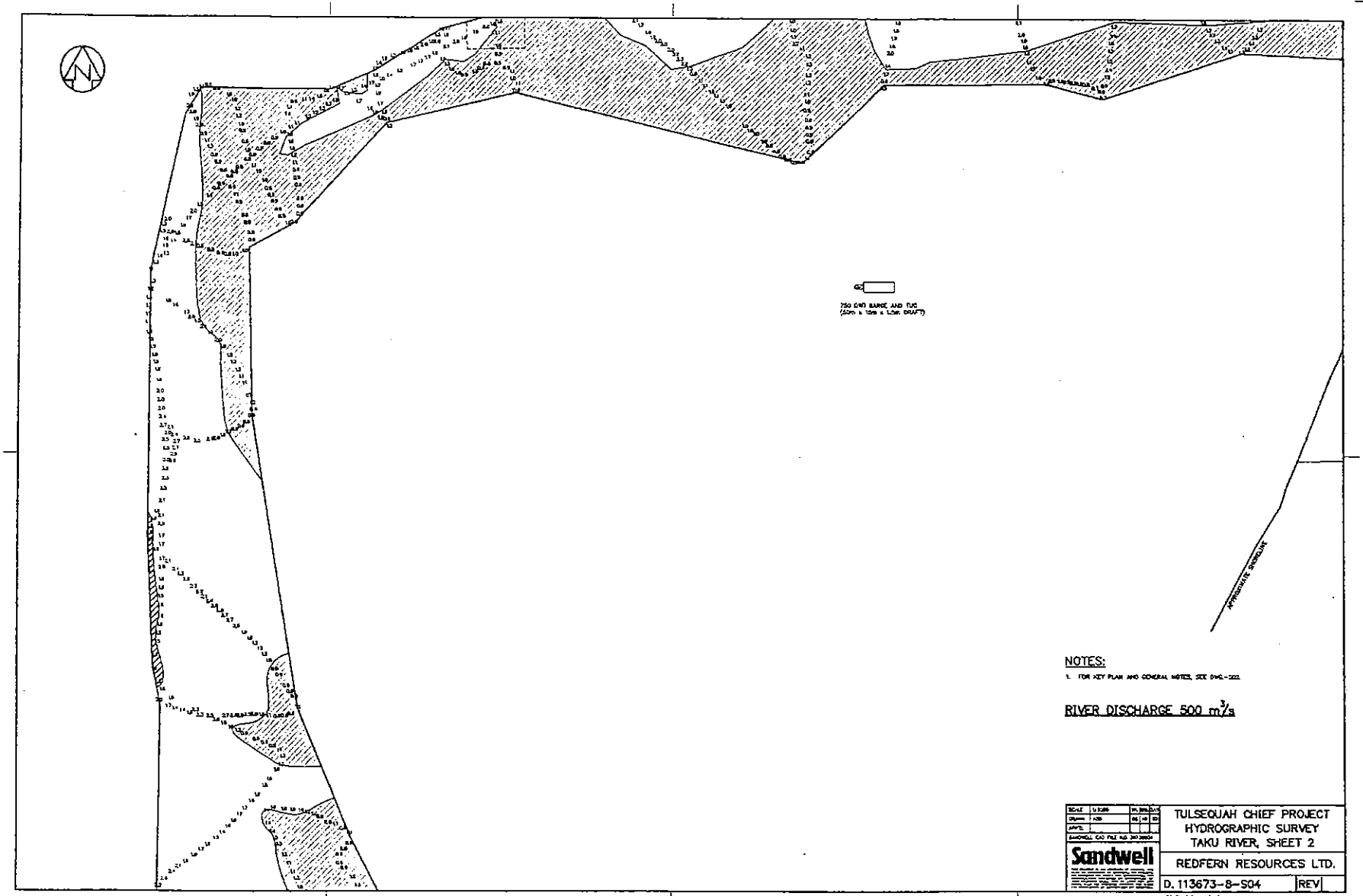
Sandwell

TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER, SHEET 1

REDFERN RESOURCES LTD.

D. 113673-8-S03 | REV

95/11/01 13:39



NOTES:

1. FOR KEY PLAN AND GENERAL NOTES, SEE DWG.-002.

RIVER DISCHARGE 500 m^3/s

SCALE	1:2000		
DRAWN			
APPR'D			
SANDWELL CAD FILE NO. 3413-0004			

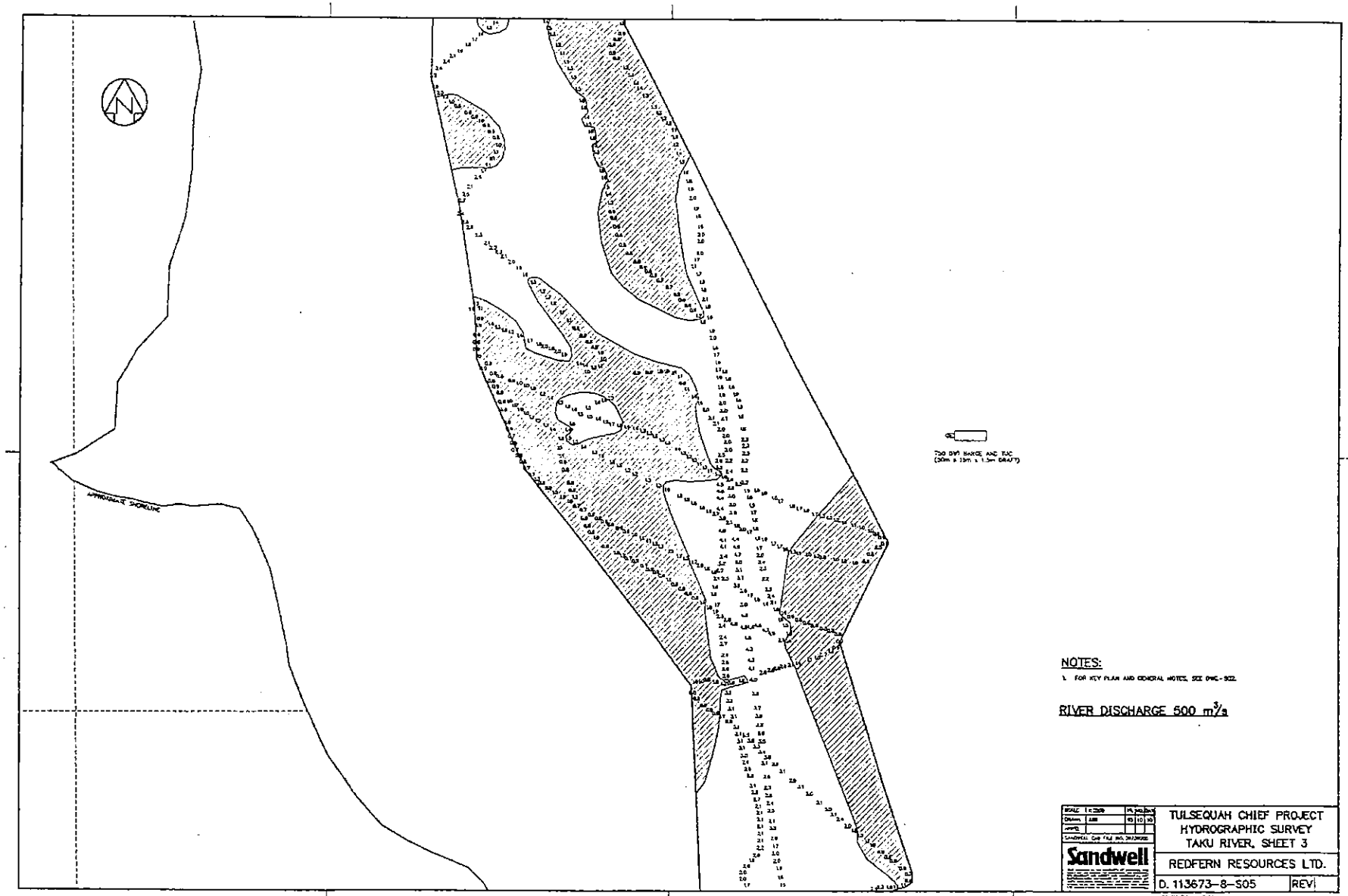
Sandwell

TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER, SHEET 2

REDFERN RESOURCES LTD.

D. 113673-8-S04 | REV

93/11/22 12:12



NOTES:

1. FOR KEY PLAN AND GENERAL NOTES, SEE DWG-502.

RIVER DISCHARGE 500 m^3/s

SCALE 1:2000	PA	MO	DM
Drawn: AMB	93	10	10
APPD:			
SANDWELL CAD FILE NO. 3913/0005			

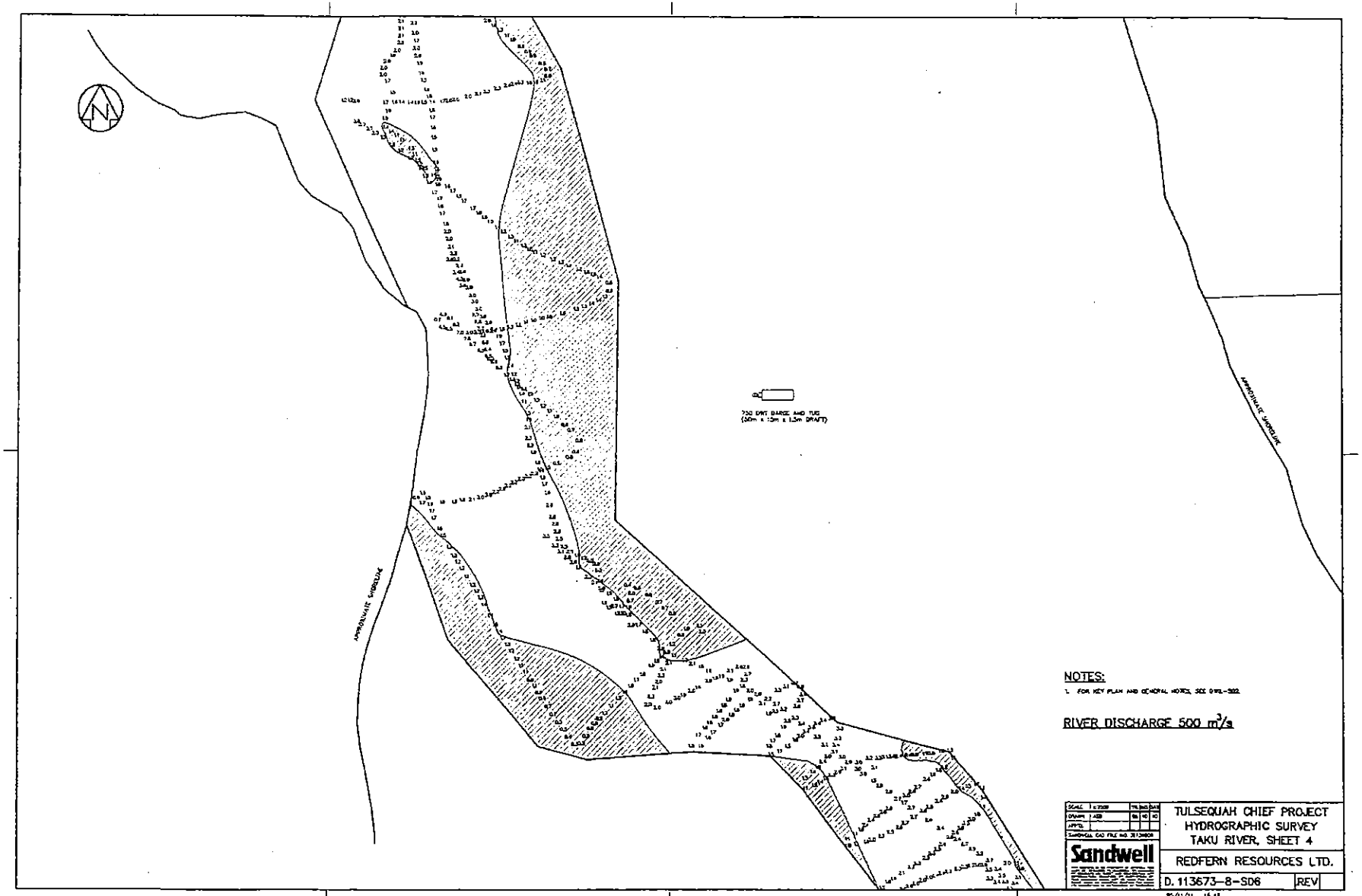
Sandwell

TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER, SHEET 3

REDFERN RESOURCES LTD.

D. 113673-8-S05 | REV1

95/11/21 16:31



NOTES:

1. FOR KEY PLAN AND GENERAL NOTES, SEE 0192-302.

RIVER DISCHARGE 500 m^3/s

SCALE 1:2000	TRIB.	DATE	
DRAWN JGB	BS	10	10
APPD.			
SANDWELL CAD FILE NO. 3013808			

Sandwell

TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER, SHEET 4

REDFERN RESOURCES LTD.

D. 113673-8-SD6 | REV

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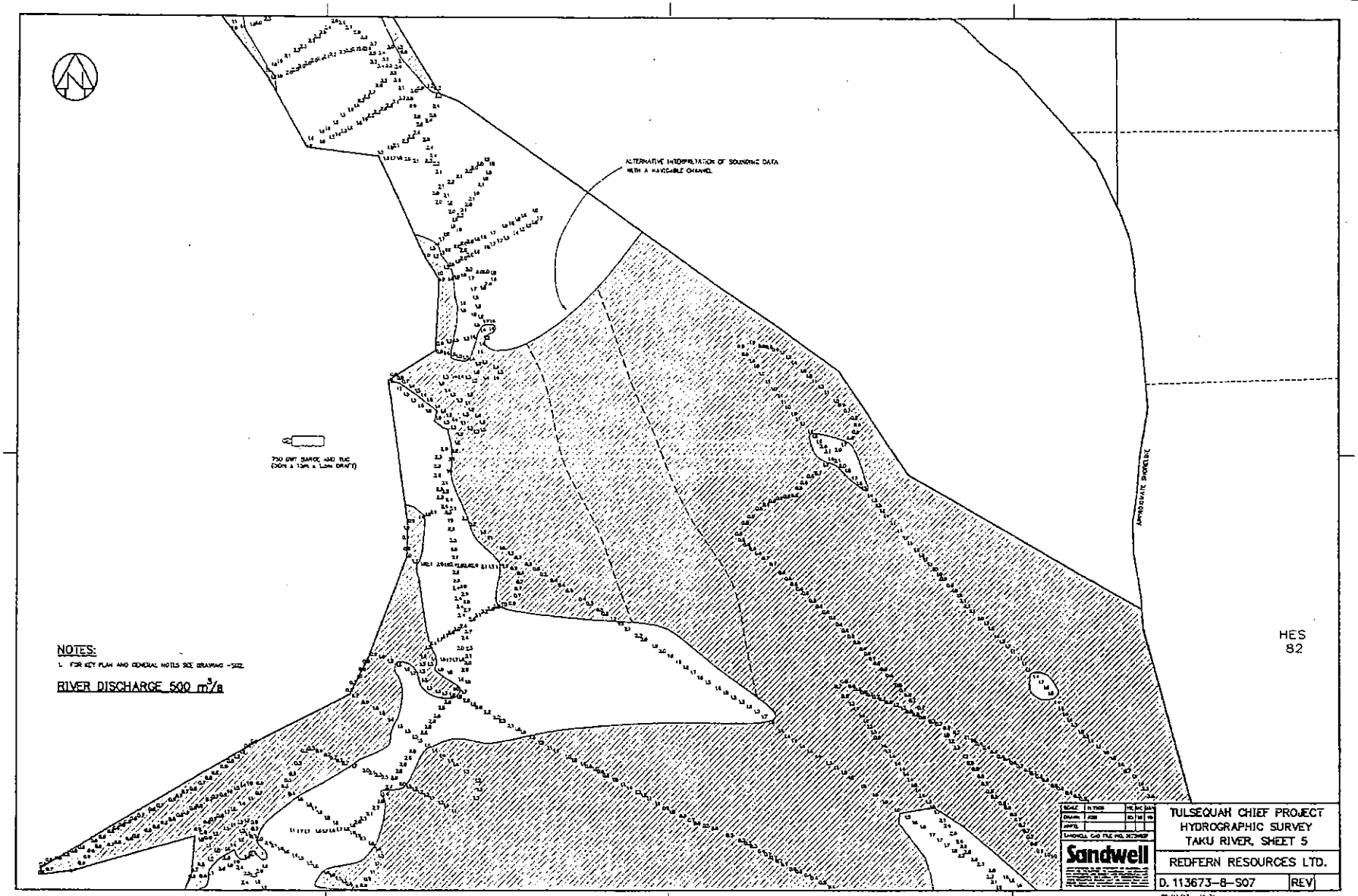
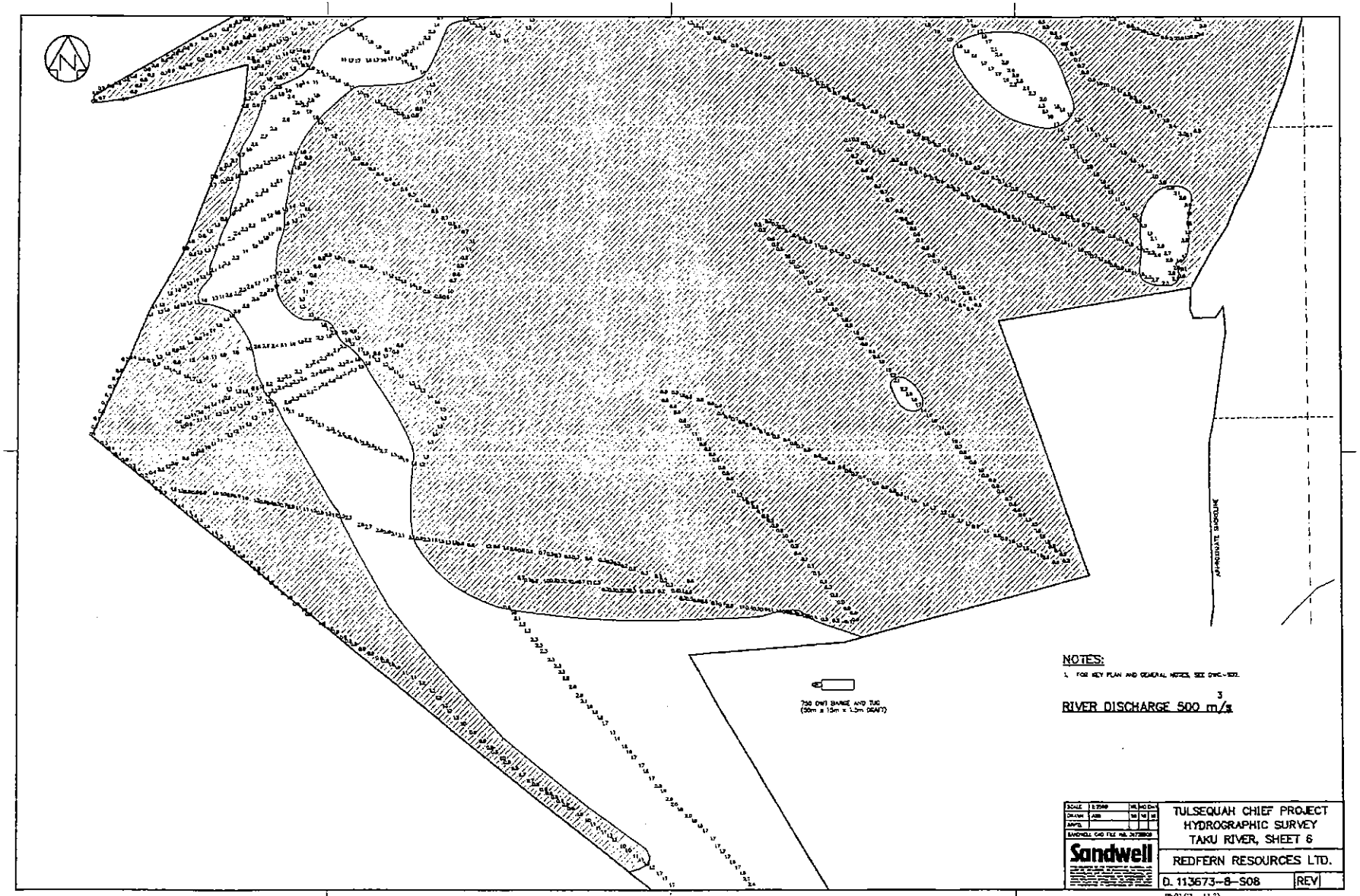
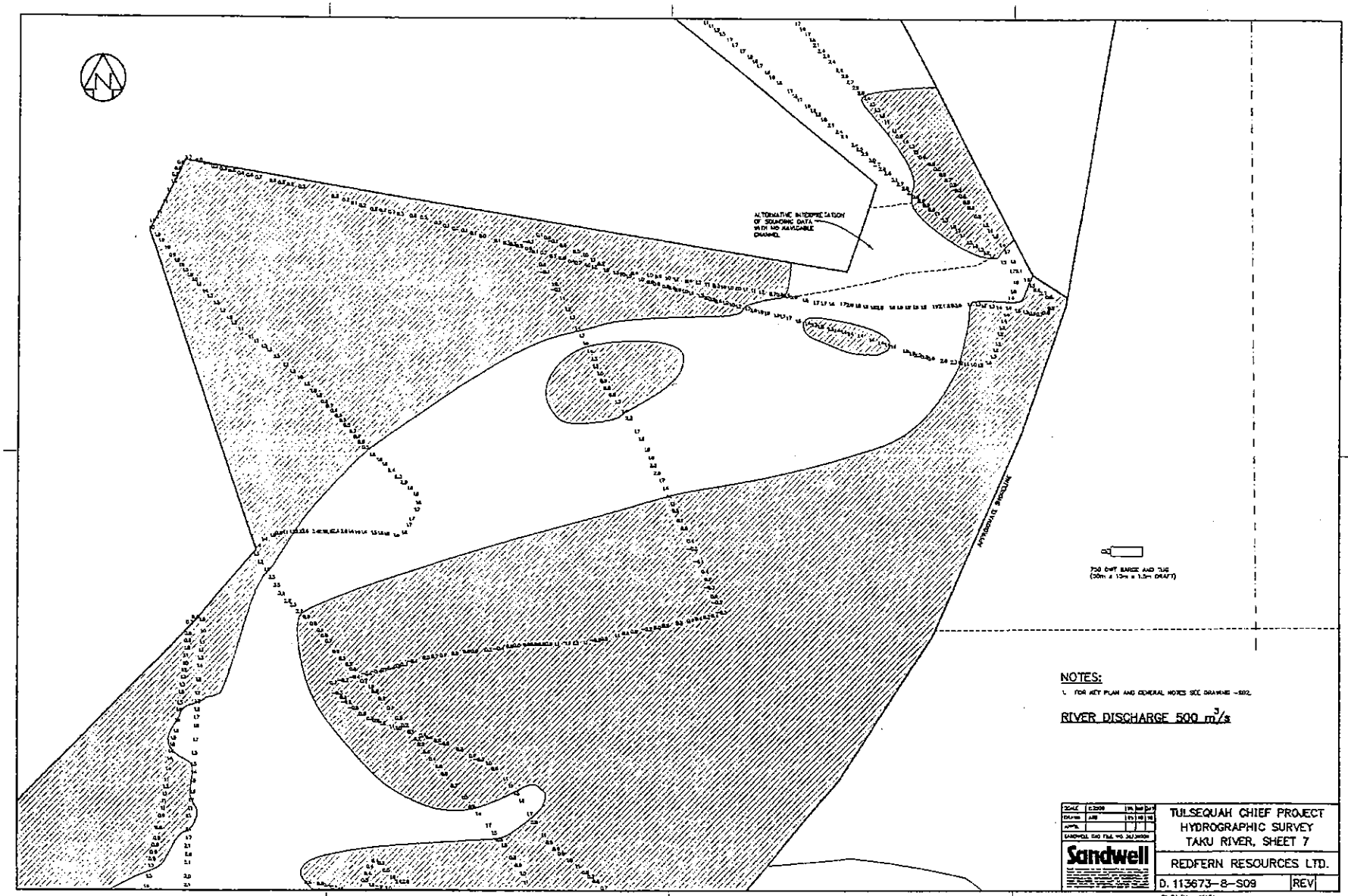

ALTERNATIVE INTERPRETATION OF SOUNDING DATA WITH A NAVIGABLE CHANNEL
APPROXIMATE SHORELINE
HES 82
NOTES:
1. FOR KEY PLAN AND GENERAL NOTES SEE DRAWING -S012.
RIVER DISCHARGE 500 m³/s
TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER, SHEET 5
REDFERN RESOURCES LTD.
Sandwell
D. 113673-8-S07
REV


700 DWT BARGE AND TUG
(50m x 15m x 1.5m DRAFT)
NOTES:
1. FOR KEY PLAN AND GENERAL NOTES, SEE DWG.-S02.
RIVER DISCHARGE 500 m³/s
TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER, SHEET 6
REDFERN RESOURCES LTD.
Sandwell
D. 113673-8-S08
REV



NOTES:

1. FOR KEY PLAN AND GENERAL NOTES SEE DRAWING -S02.

RIVER DISCHARGE 500 m^3/s

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APPR.				

SANDWELL CAD FILE NO. 3413600H

Sandwell

TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER, SHEET 7

REDFERN RESOURCES LTD.

D. 113673-8-S09 | REV

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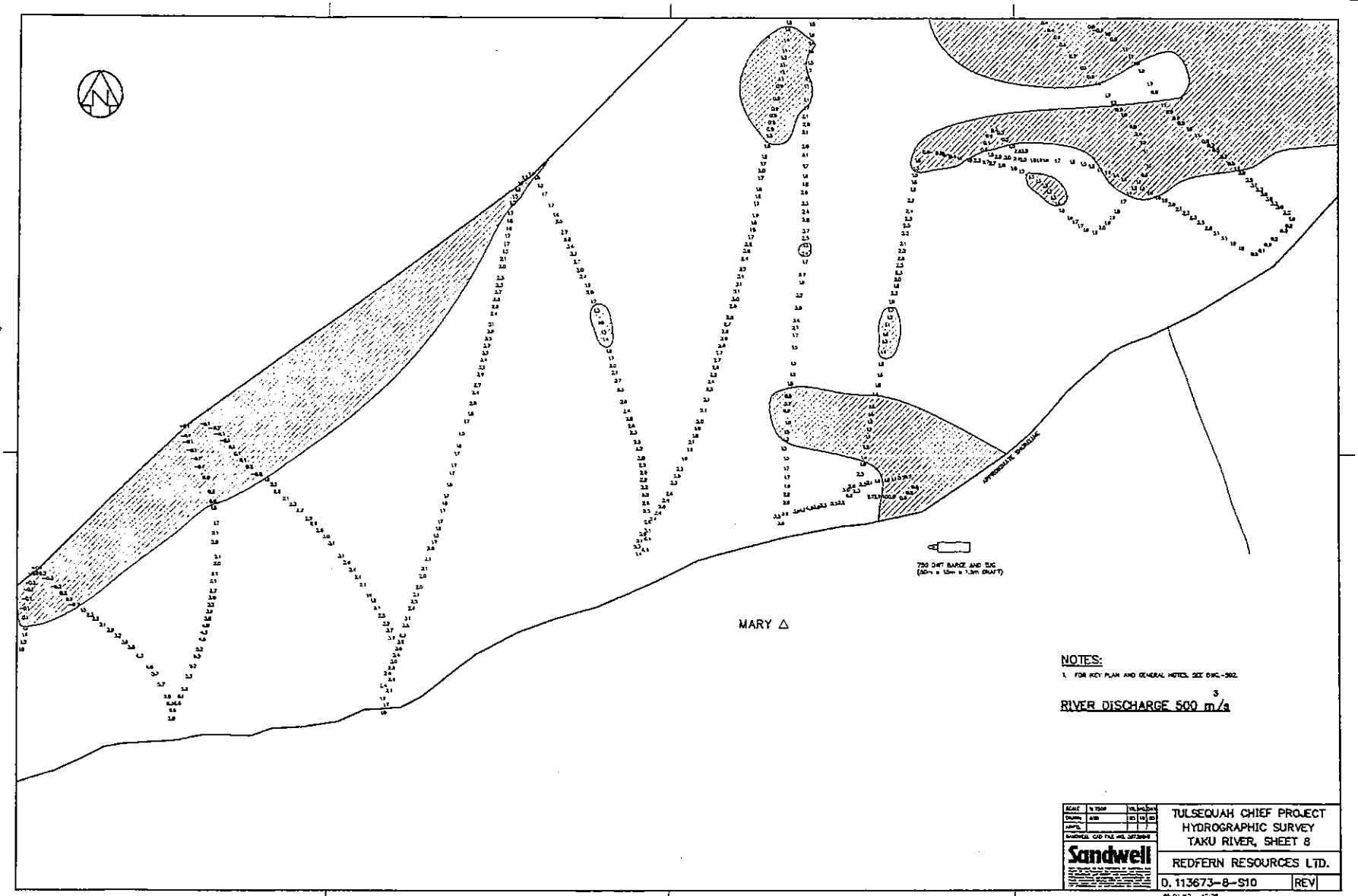

NOTES:

1. FOR KEY PLAN AND GENERAL NOTES, SEE DWG.-302.

RIVER DISCHARGE 500 m^3/s

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SANDWELL CAD FILE NO. 3973BH8				

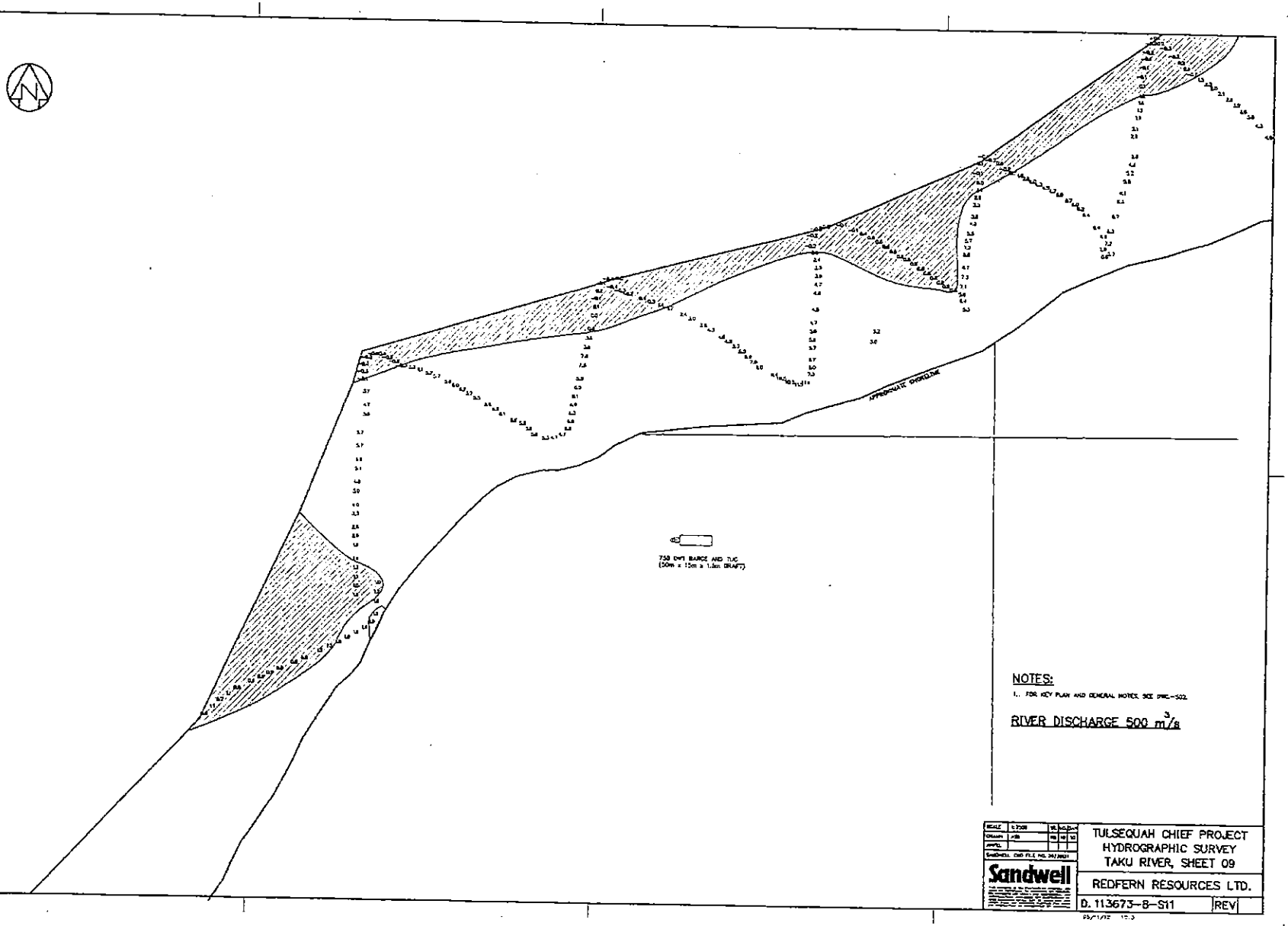
Sandwell

TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER, SHEET 8

REDFERN RESOURCES LTD.

D. 113673-8-S10 REV

95/11/13 12:28



NOTES:

1. FOR KEY PLAN AND GENERAL NOTES, SEE DWG.-502.

RIVER DISCHARGE 500 m^3/s

SCALE 1:2000			
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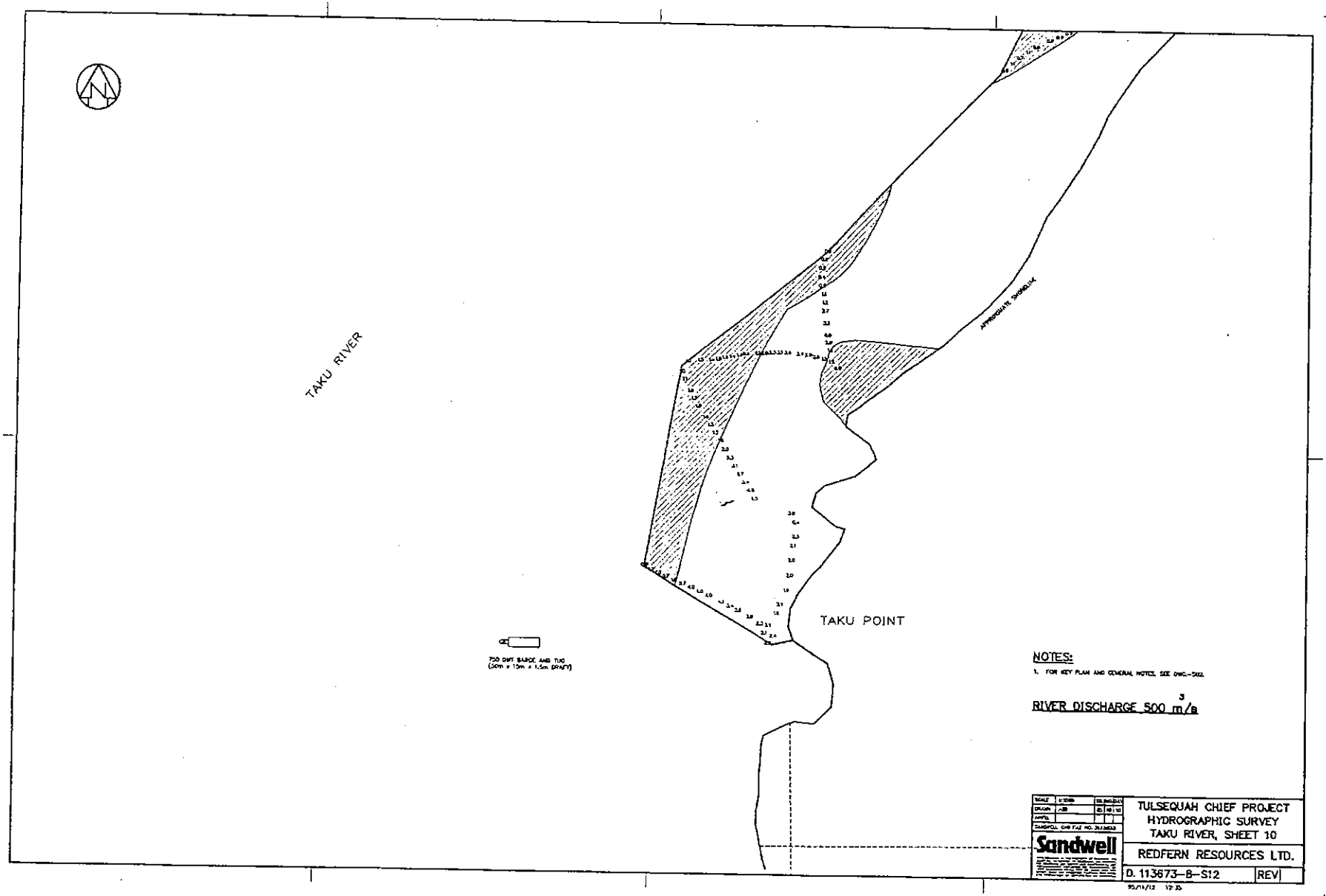
APPD.			
SANDWELL CAD FILE NO. 267.DWG			

Sandwell

TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER, SHEET 09

REDFERN RESOURCES LTD.

D. 113673-8-S11 | REV



NOTES:

1. FOR KEY PLAN AND GENERAL NOTES, SEE DWG.-5002.

RIVER DISCHARGE 500 m^3/s

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APPR.			
DARGPOLL CAD FILE NO. 3613603			

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TULSEQUAH CHIEF PROJECT
HYDROGRAPHIC SURVEY
TAKU RIVER, SHEET 10

REDFERN RESOURCES LTD.

D. 113673-B-S12 | REV

95/11/12 12:35

APPENDIX B

ALS CONTROL STATION DESCRIPTIONS

PROJECT CONTROL

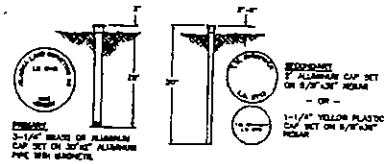
STATION	U.T.M. COORDINATES NORTHING	U.T.M. COORDINATES EASTING	ELEVATION METERS
"LET" - BASIS OF COORDINATES			
"LET"	(N 6,469,779.999)	(E 355,484.474)	5.03
"UP" (RECORD)	(N 6,472,966.286)	(E 357,471.355)	(5.68)
"UP" (FIELD)	N 6,472,965.257	E 357,470.665	7.41
"BM-1"			8.04
"BM-2"	N 6,473,770.693	E 357,531.926	11.00
"BM-3"			12.69
"RING"	N 6,473,964.764	E 357,561.653	7.035
"MARY" (RECORD)	(N 6,475,775.420)	(E 360,651.454)	(5.78)
"MARY" (FIELD)	N 6,475,777.481	E 360,653.176	5.94
"SWEDE"	N 6,477,721.748	E 359,723.590	4.85
"MOSS"	N 6,478,732.498	E 362,392.432	7.071
"BRASS"	N 6,481,194.695	E 359,342.571	7.41
"IVORY SNOW"	N 6,482,933.392	E 361,347.400	8.99
"BAR"	N 6,484,172.991	E 361,546.735	5.94
"JOHNSON"	N 6,485,347.746	E 362,879.695	8.153
"TAKU LODGE"			8.331

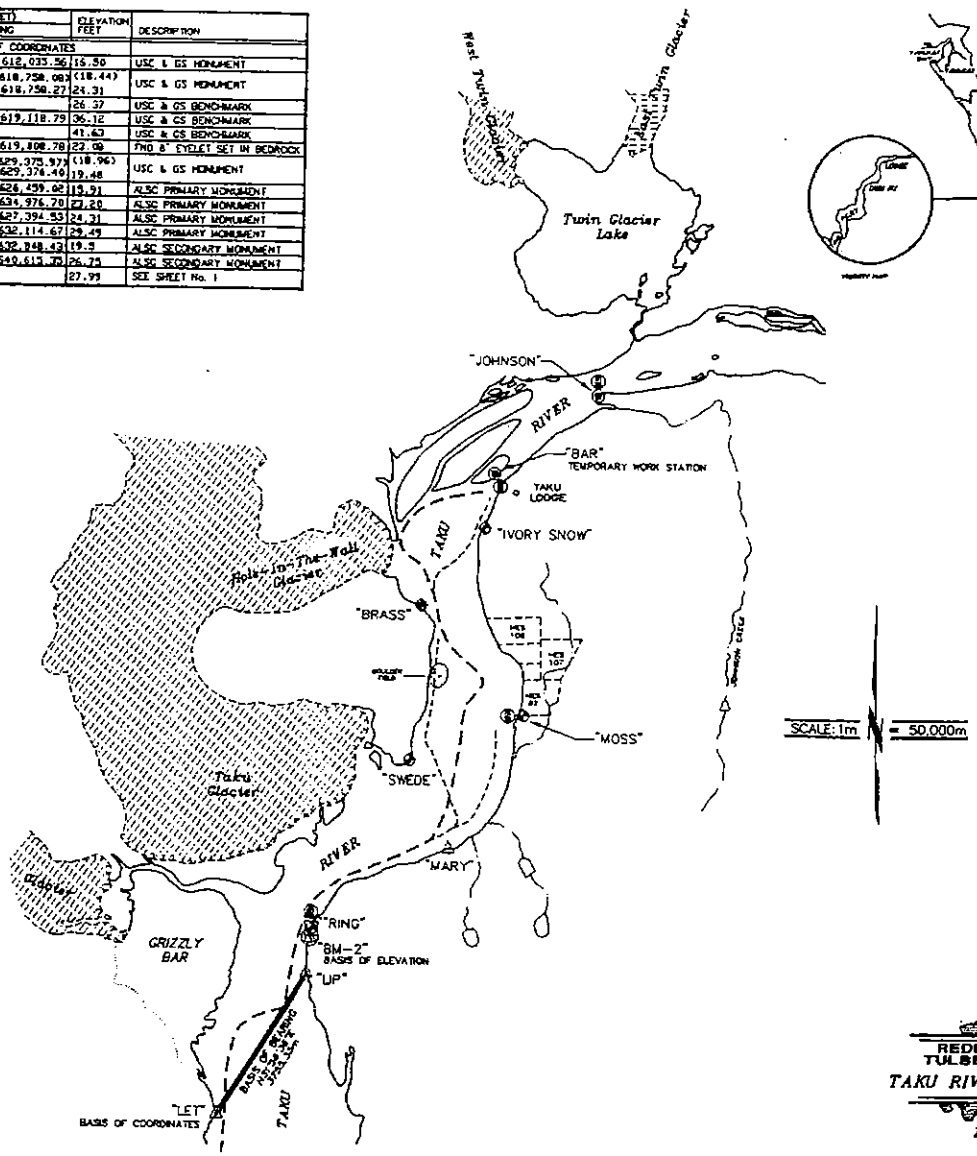
1927 N.A.D. (FEET) NORTHING	EASTING	ELEVATION FEET	DESCRIPTION
"LET" - BASIS OF COORDINATES			
N 2,396,385.02	E 2,612,035.56	16.50	USC & GS MONUMENT
(N 2,396,709.98)	(E 2,618,758.08)	(18.44)	USC & GS MONUMENT
N 2,396,709.97	E 2,618,758.27	24.31	
		26.37	USC & GS BENCHMARK
N 2,399,344.68	E 2,619,118.79	36.12	USC & GS BENCHMARK
		41.63	USC & GS BENCHMARK
N 2,399,379.36	E 2,619,808.78	22.08	FND 8" EYELET SET IN BEDROCK
(N 2,405,725.43)	(E 2,629,375.97)	(18.96)	USC & GS MONUMENT
N 2,405,723.97	E 2,629,374.40	19.48	
N 2,412,163.59	E 2,626,459.02	15.91	ALSC PRIMARY MONUMENT
N 2,415,313.02	E 2,634,976.70	23.20	ALSC PRIMARY MONUMENT
N 2,423,341.57	E 2,627,394.53	24.31	ALSC PRIMARY MONUMENT
N 2,429,154.33	E 2,632,114.67	29.49	ALSC PRIMARY MONUMENT
N 2,433,204.66	E 2,632,248.43	19.5	ALSC SECONDARY MONUMENT
N 2,439,878.83	E 2,640,613.35	26.25	ALSC SECONDARY MONUMENT
		27.99	SEE SHEET No. 1

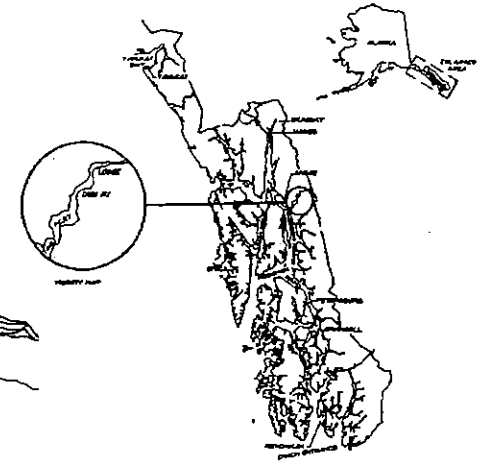
LEGEND:

- 1995 WATER LEVEL GAUGE LOCATION
- 5/8" REBAR WITH YELLOW PLASTIC SURVEY CAP
- ALSC WORK STATION (SEE MONUMENT DESCRIPTION)
- PRIMARY MONUMENT SET THIS SURVEY
- USC & GS MONUMENT RECOVERED THIS SURVEY
- USC & GS BENCH MARK RECOVERED THIS SURVEY
- PRIMARY ROUTE SURVEY
- SECONDARY ROUTE SURVEY

TYPICAL MONUMENTS AND SETTINGS:







LOCATION MAP

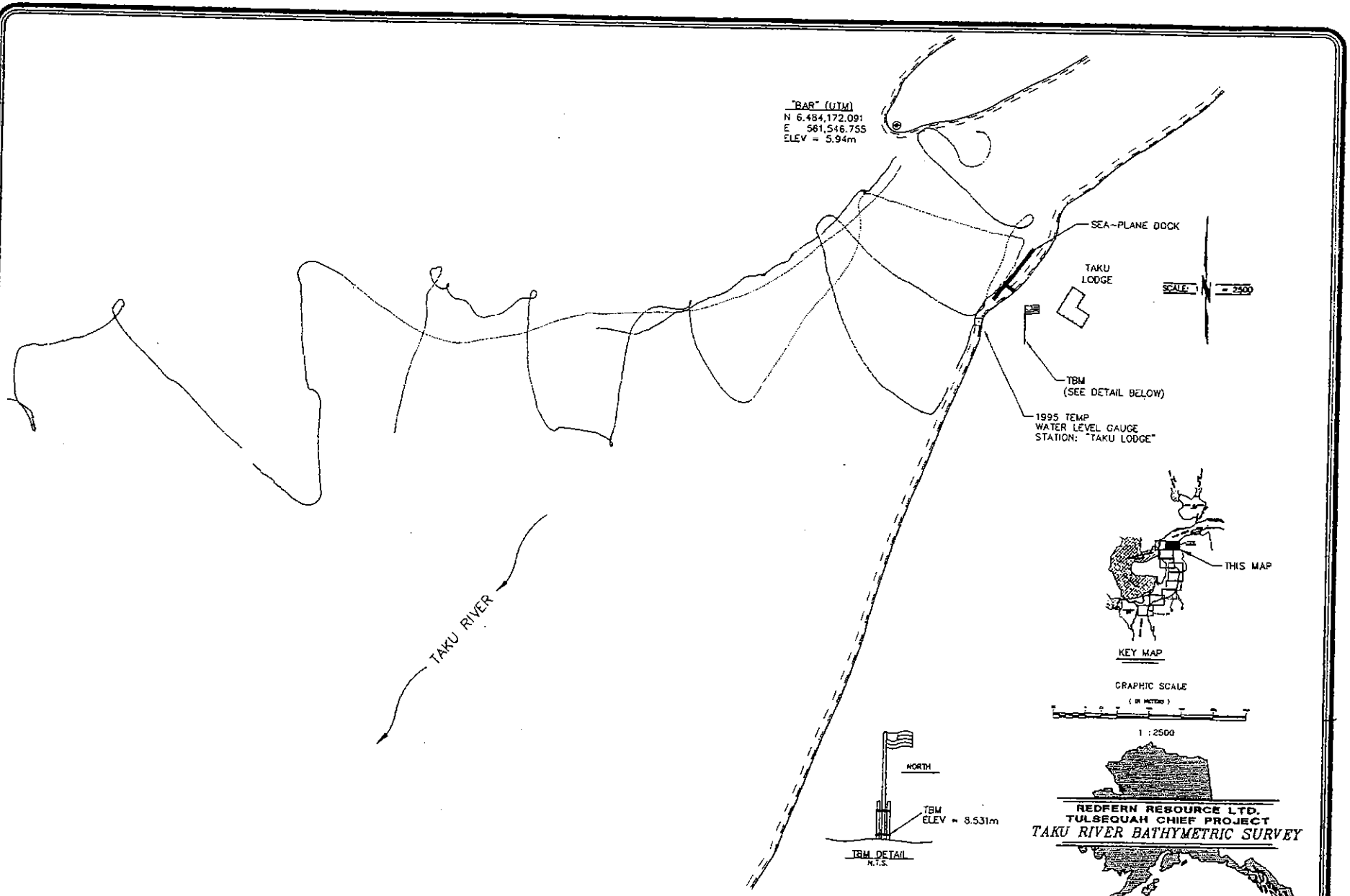
SCALE: 1m = 50,000m

REDFERN RESOURCE LTD.
TULSEQUAH CHIEF PROJECT

TAKU RIVER BATHYMETRIC SURVEY

ALASKA LAND SURVEYING CO.

PREPARED BY: ALASKA LAND SURVEYING CO. - JUNEAU, ALASKA - (907) 789-8000, FAX: (907) 789-4324



ALASKA LAND SURVEYING CO.