Partridge River Watershed
Winter 2010-2011
Base Flow Analysis

Minnesota Department of Natural Resources

Division of Ecological and Water Resources

Water Monitoring and Surveys Unit

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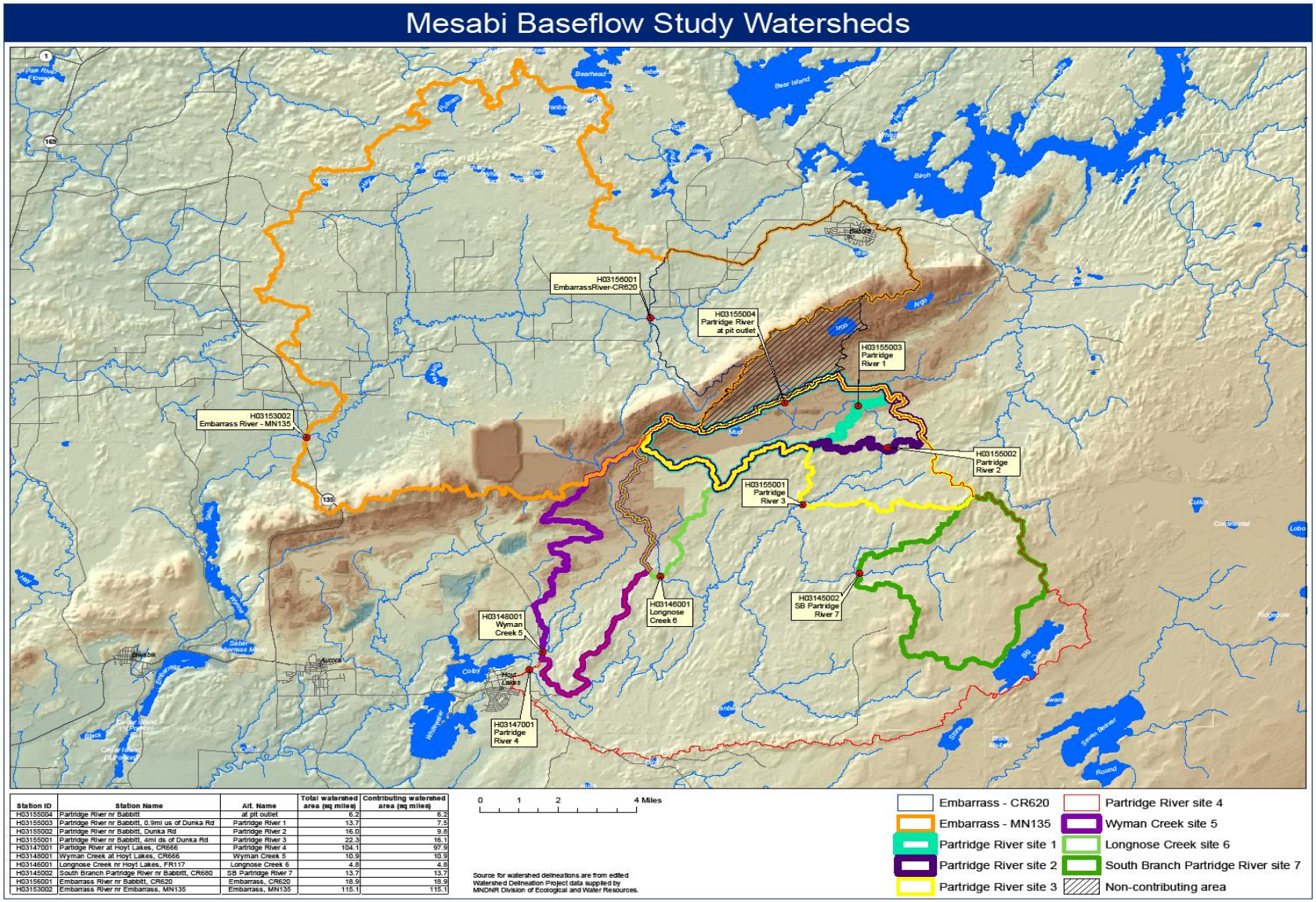
During the winter of 2010-2011 the Minnesota Department of Natural Resources (MDNR) performed a series of flow measurements to evaluate the base flow within the Partridge River Watershed. The objectives of this data collection and analysis were to:

- Determine the flow contributions and discharge increases within the system from the headwaters of the Partridge River to the inlet to Colby Lake.
- To quantify if possible, flow increases to the Partridge River from deep groundwater and near bank within the measurement reaches.

This study is a follow up to initial base flow measurements performed by MDNR November 2008 (see attached memo January 27, 2010).

The MDNR collected a series of three flow measurements from January – March 2011 at six locations within the Partridge River Watershed above Colby Lake (see figure 1). Discharge measurements were made at the outfall of the dewatering system for Northshore Mining near the headwaters of the Partridge River to determine mining activity contributions and establish the upper boundary conditions for the base flow evaluation. The former USGS stream gage at County Road 666 just upstream of Colby Lake was defined as the lower boundary of the study segment. Flows were measured downstream of the headwaters at road crossings and key tributary contribution points that allowed access during the winter.



Station ID	Station Name	Alt. Name	Total watershed area (sq miles)	Contributing watershed area (sq miles)
H03156004	Partridge River nr Babbitt	at pit outlet	6.2	6.2
H03155003	Partridge River nr Babbitt, 0.9mi us of Dunka Rd	Partridge River 1	13.7	7.5
H03155002	Partridge River nr Babbitt, Dunka Rd	Partridge River 2	16.0	9.8
H03155001	Partridge River nr Babbitt, 4mi ds of Dunka Rd	Partridge River 3	22.3	16.1
H03147001	Partridge River at Hoyt Lakes, CR666	Partridge River 4	104.1	97.9
H03148001	Wyman Creek at Hoyt Lakes, CR666	Wyman Creek 5	10.9	10.9
H03146001	Longnose Creek nr Hoyt Lakes, FR117	Longnose Creek 6	4.8	4.8
H03145002	South Branch Partridge River nr Babbitt, CR680	SB Partridge River 7	13.7	13.7
H03156001	Embarrass River nr Babbitt, CR620	Embarrass, CR620	18.9	18.9
H03153002	Embarrass River nr Embarrass, MN135	Embarrass, MN135	115.1	115.1

Figure 1.

Equipment and Measurement Methods

Standard USGS methods for discharge measurement during ice and open water conditions were used to determine flows within the system (see *USGS Water Supply Paper 2175*). Where depths were greater than 0.8 ft. an Acoustic Doppler Current Profiler (ADCP) was used to measure. Price Mini Meters (pygmy) were used were depths and ice limited the use of the ADCP.

General Fall and Winter Stream Flow Conditions

Typically during the fall an increase in stream flows occurs as vegetation declines or becomes dormant resulting in less evapo-transpiration. Precipitation generally increases in the early fall further increasing fall stream flows, soil moisture and bank storage. As air temperatures decline precipitation falls as snow and contributions to the stream begin to decline. This decline in stream flows in a natural system continues throughout the winter as bank storage and near surface soil storage provides less inflow to the stream. Variability in the gradual flow decline may occur as water in the stream goes into ice storage. The formation of ice jams and the sudden release of water from these jams will also cause brief fluctuations in discharge. Air temperatures above freezing for more than two or three consecutive days can also result in increased flows due to snow melt.

Partridge River Data Interpretation Considerations

- Discharge measurement conditions in the study area were typically difficult to perform due to ice. Edge areas required estimation, rocks and bottom variability caused flow obstructions that were difficult to detect under the ice and caused turbulence during some measurements. These conditions were unavoidable due to the limited number of accessible measurement locations.
- Cliffs Erie pumping throughout the winter was inconsistent making it difficult to establish steady state conditions for the contributing watershed in the upstream section.
- Wetlands at the upstream end likely slowed and stored large proportions the mine discharged waters (*gage #H03155004*) when compared to the measured flows at the 0.9 mile location (*gage #H03155003*).
- Air temperatures well below freezing caused significant flow losses along the measured reaches due to water going into storage as ice.
- Although not documented during this study, ice jams are typical during the winter. Between measurement locations, ice may have also caused flow variability as water backed up behind ice jams and then released when the jams cleared.

Table 1 summarizes the flow measurements collected at each location from January 24 to March 16, 2011. (For comparative purposes additional flow measurements along the Embarrass River collected for a different study are also included.)

Site Name	Gage ID	Nov 24-26, 2008 Q (cfs)	Dec 15-16, 2010 Q (cfs)	Jan 25-26, 2011 Q (cfs)	Jan 25-26, 2011 H_20 Temp (F)	Feb. 15-16, 2011 Q (cfs)	Feb. 15-16, 2011 H_20 Temp (F)	Mar. 15-16, 2011 Q (cfs)	Mar. 15-16, 2011 H_20 Temp (F)
Partridge River nr Babbitt, RR tracks	H03155004	0	9.1	0 *		4.3		3.7	
Partridge River nr Babbitt, 0.9mi us of Dunka Rd	H03155003	7.6	0.41 **	5.5	32	5.1	32	4.2	32
Partridge River nr Babbitt, Dunka Rd	H03155002	10.2		4.1	31	4.2	32	6.6	32
Partridge River nr Babbitt, 4mi ds of Dunka Rd	H03155001	14.1							
Partridge River at Hoyt Lakes, CR666	H03147001	41.9		9.1	31	7.3		6.9	
Wyman Creek at Hoyt Lakes, CR666	H03148001	5.7		1.5		1.6		1.1	
Longnose Creek nr Hoyt Lakes, FR117	H03146001	2.0		0.25		0.53		0.44	
South Branch Partridge River nr Babbitt, CR680	H03145002	6.1		0.2		0.17		0.37	
Embarrass R @ CR 620	H03156001			4.7	33	6.1	33		
Embarrass R @ CR 135	H03153002			13.9	32	15	34	12.3	

* Upstream pumping by Cliffs was variable during previous days and during measurement time period.
**Measurement upstream of road culverts and may not represent the entire upstream flow contribution

Table 1. Discharge Measurement Summary

Note that table 1 includes the November 2008 measurements for comparison purposes. During November 2008 flows were significantly greater than those measured during the winter of 2010-2011 and open water conditions were found throughout the study segment in November 2008. Fall precipitation during 2008 was above average from September through November and likely contributed to the higher base flow conditions. The average precipitation for the Hoyt Lake area is 7.36 inches (September-November). The total precipitation for 2008 for September – November was 11.35 inches, while total accumulations for September – November 2010 were 7.6 inches (source: MDNR State Climatology Office).

During the winter of 2010-2011 from January to March the discharge varied between measurement locations and through time as shown in table 1.

For example, the flow measurements for January and February showed a decline along the Partridge River between the 0.9 mile road crossing (*H03155003*) and the Dunka Road 4 mi (*H03155001*) crossing

downstream. Typically flow increases as the drainage increases. The decline in flows in this segment is likely due ice and wetland storage within the reach at the time of measurement. Later in March, the flow measurements indicated an increase in discharge in a downstream fashion between these two locations.

A gradual decrease in discharge through time is shown in the flow measurements from January to March at the 0.9 road (*H03155003*) and CR666 (*H03147001*) locations. This is typical for winter base flow conditions. The Dunka Road gage site (*H03155002)* had an increase in flows from the February to the March discharge measurements. The increase in discharge between the two measurements at the Dunka Road site may be due to the brief melt that occurred in February or ice storage release between the measurement time periods.

The variability of the measurements through time was likely due to ice formation, brief air temperature rises, storage or from variable pumping rates at the upstream study boundary. The measurements do not show consistent, significant pick up in discharge along the Partridge River.

Site Name	**Gage ID**	Area (sq. mi.)	Nov 24-26 2008	Qsm/ reach	Dec 15-16,2010	Jan 25-26 2011	Qsm/ reach	Feb 15-16, 2011	Qsm/ reach	Mar. 15-16, 2011	Qsm/ reach
Partridge River nr Babbitt, RR tracks	H03155004										
Partridge River nr Babbitt, 0.9mi us of Dunka Rd	H03155003	13.7	0.55	0.55	0.03	0.40	0.40	0.37	0.06	0.31	0.04
Partridge River nr Babbitt, Dunka Rd	H03155002	16.0	0.64	1.17		0.26	-0.62	0.26	-0.40	0.41	1.06
Partridge River nr Babbitt, 4mi ds of Dunka Rd	H03155001	22.3	0.63								
Partridge River at Hoyt Lakes, CR666	H03147001	104.1	0.40			0.09		0.07		0.07	
Wyman Creek at Hoyt Lakes, CR666	H03148001	10.9	0.53			0.14		0.15		0.10	
Longnose Creek nr Hoyt Lakes, FR117	H03146001	4.8	0.42			0.05		0.11		0.09	
South Branch Partridge River nr Babbitt, CR680	H03145002	13.7	0.45			0.01		0.01		0.03	
Embarrass R @ CR 620	H03156001	18.92				0.25		0.32			
Embarrass R @ CR 135	H03153002	115				0.12		0.13		0.11	

Table 2. Discharge per square mile of drainage area

Examining the discharge as a proportion of the drainage area can help define the base flow inputs to a watershed and pinpoint areas of the watershed with larger flow contributions. Table 2 summarizes the discharge measurements as a ratio of watershed drainage area.

Discharge per square mile of drainage (Qsm) was relatively consistent at the Partridge River at CR666, tributary sites and along the Embarrass River. The discharge per square mile at the upstream Partridge River locations was relatively variable through time. It is likely that the variability is caused by the flow variation due to the proximity from North Shore Mining's discharge point.

The air temperature was also monitored at each location during the measurements. Air temperatures ranged from 15 to 50 degrees Fahrenheit. Water temperatures were sampled at locations where the ADCP could be deployed. As shown in table 1, water temperatures were at freezing for all locations sampled.

The Partridge River was completely ice covered throughout the observable reaches and measurement locations below the Cliffs Erie discharge point down to the C.R. 666 location. Ice depths at the measurement sites ranged from 0.5 ft. to 1.5 ft. throughout the study period. Open water on the Partridge River was only found at the C. R. 666 location directly under the bridge where a rock riffle caused sufficient turbulence. Thin ice 0.2 to 0.5ft was also observed at the measurement sites on the Longnose and Wyman Creek sites due to turbulence at riffle areas.

Streams and rivers with significant ground water contributions remain open, may have thin layers of ice or ice with a spongy consistency. For example, MDNR conducted a surface-groundwater interaction study on the Straight River near Park Rapids from 1996-1998 and monitored flows continuously, including winter time periods. When air temperatures were below -5 Fahrenheit, the four gage location along the 12 mile study reach of the Straight River remained open or had thin layers of ice, while discharge between gage locations increased consistently by 30 – 50% and water temperature remained above freezing.

Ice density and thickness at the measurement points along the Partridge River were similar to over 40 other stream gage sites measured by MDNR across the state during the same period of 2011.

Summary and Conclusions

- Twenty two discharge measurements were made within the Partridge River Watershed from January to March, 2011.
- Discharges were variable between locations and through time likely due to inconsistent pumping rates at the upstream end, ice formation, wetland storage and a brief thaw period.
- Water temperatures where measured, were at or near freezing.
- The Partridge River and tributaries were 100% ice covered at observable locations, with the exception of a riffle area at County Road 666.

Based on the data collection during the study period, it is unlikely that significant amounts of groundwater contributed to the base flows of the Partridge River. Ice thickness, water temperatures and limited pick up in discharge within the system indicate bank storage provided the most significant contribution to stream flows.

Spot measurements of discharge do not provide the value of continuous discharge monitoring to evaluate incremental changes in flow on a seasonal, daily or hourly basis. Clearly the addition of continuous monitoring gaging stations within the Partridge River watershed would provide for a more thorough evaluation of the watershed characteristics and ground water contributions.

Questions regarding this study can be directed to Greg Kruse, Division of Ecological and Water Resources, Minnesota Department of Natural Resources (greg.kruse@state.mn.us, 651-259-5686).

Photo summary of conditions at flow measurement locations within the Partridge River Watershed, February 15th and 16th, 2011.

Cliffs Erie discharge point to the upper Partridge River, February 15, 2011 (MDNR gage # H03155004)

Partridge River nr Babbitt, 0.9mi upstream of Dunka Rd., looking downstream. February 15, 2011 (MDNR gage # H03155003)

Partridge River nr Babbitt, Dunka Rd, looking upstream, February 15, 2011 (MDNR gage #H03155002)

Partridge River at Hoyt Lakes, CR666, February 16, 2011 MDNR (gage # H03147001)

South Branch Partridge River nr Babbitt, CR680, looking downstream, February 16, 2011 (MDNR gage # H03145002)

Wyman Creek at Hoyt Lakes, CR666, looking upstream, February 16,2011 (MDNR gage# H03145002)

Longnose Creek nr Hoyt Lakes, FR117, February 16, 2011 (MDNR gage #H03146001)