APPENDIX B: Guidance for Voluntary Pilot Projects

The Applicant has agreed to make bypass flows available for Voluntary Pilot Projects (VPPs) during the Interim Period. The Interim Period begins "upon issuance and acceptance by Denver Water of permits necessary for the Moffat Project" and continues until the project "becomes operational"[1]. VPPs conducted during the Interim Period will be devoted to evaluating the temperature benefit from bypass flows and for developing a decision matrix to guide subsequent bypass actions.

During the Interim Period, the amount of water available for VPPs is not fixed, but depends on snowpack, reservoir storage, summer forecasts, and maintenance or operational constraints on movement of water. A reasonable estimate of availability should be possible by May each year, which is ample time to establish a framework for the VPP to be conducted during the summer.

At least three locations offer potential for VPPs: Ranch Creek, Fraser mainstem, and St Louis Creek. Ranch Creek is especially important in view of the present magnitude and frequency of temperature exceedances; direct mitigation would be highly desirable. However, Ranch Creek is also a complicated location for a VPP because of diversions and the potential importance of the many beaver dams. The Fraser mainstem offers the best opportunity for investigating the longitudinal persistence of benefit from bypass flows because of the cold temperatures and availability of water in Vasquez Creek. However, temperature problems are not common in the mainstem above Granby.

The Applicant will submit a study plan by June 1st in each year for which bypass flows are available. The study plan will describe the objectives, monitoring locations, collection of ancillary data (e.g., air temperature, flows, travel times), and strategy for manipulating bypass flows. The plan should also explain circumstances where options for monitoring locations, and thus also for study design, are constrained by access to private land. The Division will review the plan and recommend any changes within 30 days.

Study Design

Each study will have general objectives related to evaluating the benefits of bypass flows. These objectives specify the stream to be evaluated (e.g., Ranch Creek), the strategy for manipulating bypass flows (amount, source, and scheduling), and the basis for detecting the benefit as the bypass water moves downstream. Although the

[1] As per the CRCA: "The capacity of Gross Reservoir has been enlarged, and water has been diverted and stored in the enlarged portion of Gross Reservoir."

time window for the studies is relatively brief (July 15 – August 31), there may sufficient time to evaluate multiple objectives with each VPP.

Ranch Creek and the Fraser River mainstem are well suited for study in the sense that both have real-time monitoring stations. Ranch Creek is more complicated in terms of options for bypass flows and by virtue of the numerous beaver dams along the reach of interest. One general approach would be to focus first on the Fraser River in order to test temperature metrics and develop a preliminary basis for estimating the longitudinal persistence of benefits from bypass flows.

The beaver dams along Ranch Creek pose special problems because they affect travel time and temperature in ways that must be considered in developing a study plan. Each beaver dam extends the residence time of water in the reach, and it warms the water more than would occur without the dam. Both factors are likely to affect the longitudinal persistence of benefits from bypass flows. The role of these factors could be evaluated initially without regard to bypass flows.

The VPPs are handicapped in a way because it is not possible to set up parallel streams – one with and one without bypass flows – that would facilitate a side-by-side comparison. Instead, it is necessary to vary bypass flows over short periods of time when weather conditions are expected to be relatively stable. For example, flow could be bypassed for three or four days followed by a similar period of time when there is no bypass. Alternation of flow regimes will make it easier to isolate the benefit of the bypass flows. In addition, the amount of each bypass can be varied according to the amount of water that is available, although it is important to begin with the maximum amount to make sure benefit can be detected.

There are several locations in the basin where bypass flows are available, and this offers options for mitigating elevated temperatures. However, for initial trials, it makes sense to manipulate the sources where bypass flows are likely to be largest. Having a single source, or closely spaced sources, makes it easier to determine the longitudinal extent of the benefit that bypass flows can provide. Smaller sources can be added later after a firm basis has been established for estimating the longitudinal extent of the benefit.

Scheduling bypass flows depends in part on travel times; how long does it take for the leading edge of bypass flows to reach the terminus of the study reach and how long does it take for the trailing edge to reach the terminus after the bypass flows are stopped. For example, if the travel time through the reach is approximately one day, then bypass flows should be scheduled for three or four days in order to get two or three days of stable conditions for data collection. Similar reasoning applies to the interval after bypass ceases.

Travel time determinations are an important element of scheduling decisions. Channel geometry along the Fraser mainstem may be sufficient to support these estimate, but that is unlikely to be the case in Ranch Creek due to the beaver dams. Dye tracer studies, or something comparable, are needed to provide an empirical

basis for travel times. These studies will also help determine the spacing for data loggers.

Real-time data for air temperature would be a significant addition to the studies. It would make it possible to validate that before and after bypass comparisons of stream temperature are made at times when air temperature is relatively stable.

Longitudinal Studies

For each VPP, data loggers must be closely spaced downstream of the bypass location; the real-time monitoring locations are also important, but do not provide adequate spatial resolution for assessing benefit. Ideally, the spacing should make it possible to measure the same parcel of water several times in a day. For example, if a parcel in lower Ranch Creek moves about 6 miles a day[2], placing loggers about 1 mile apart would result in a transit time of approximately 4 hours between adjacent loggers. As an initial trial, loggers could be deployed to cover a distance approximating a travel time of one day. Spacing or distance could then be adjusted as more is learned. The data loggers would be deployed only for the duration of the VPP and should be set to record at 15-min intervals, or more frequently.

The advantage of data from the data loggers, compared to sole reliance on the real-time sites, is that it is possible to frame benefit questions in terms of distance rather than just a yes or no answer. It is likely that the distance over which the benefit persists depends not only on the amount of the bypass, but also on the path it takes. In other words, we might predict that the benefit will travel farther in the Fraser River than in Ranch Creek due to factors that affect velocity (e.g., beaver dams and low gradient).

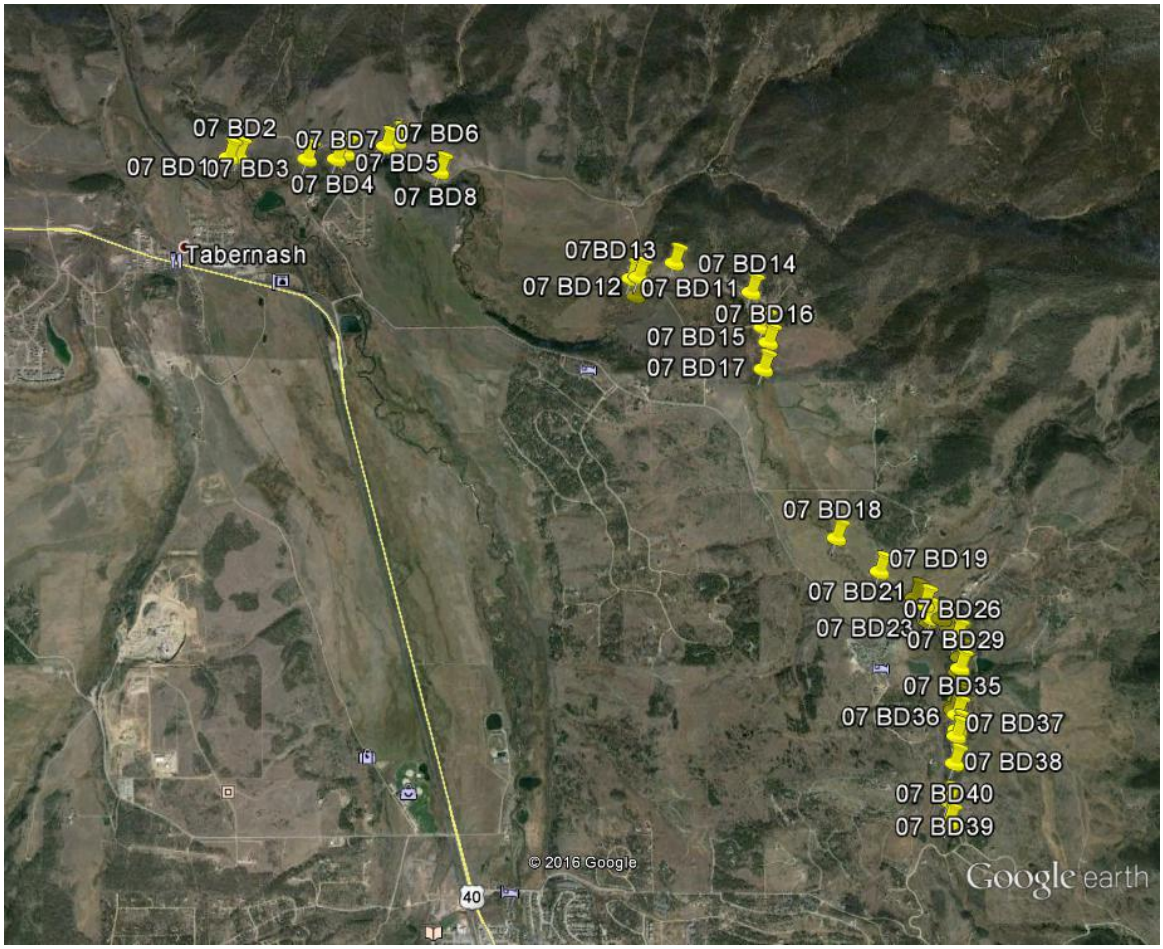
Beaver Dams

For Ranch Creek specifically, there is a need to understand more about the influence of beaver dams on stream temperature. Each beaver dam functions like a small low-head dam that creates a pool where width and depth are relatively insensitive to small variations in flow (i.e., the changes anticipated with bypass flows). Consequently, the beaver dams may result in more rapid attenuation of the benefit from bypass flows than would be expected in the absence of the dams. That information may prove valuable for developing the decision matrix and for reaching conclusions about *de minimis* benefit.

The Applicant has supplied information showing that there are almost 50 beaver dams between their diversion point and the mouth of Ranch Creek (see Figure below). The effect of beaver dams on stream temperature has been studied in other settings, and results of those studies yield some conclusions that can guide study design in Ranch Creek. Each beaver dam slows the velocity of the stream, and the longer residence

[2] Velocity is less than 1 fps at flows below 10 cfs based on field measurements at the two gages on Ranch Creek. The choice of 6 mi/d is approximate and simplifies calculations.

time warms the stream compared to what would happen in the absence of the dam. The dams also increase water depth, which tends to reduce the daily amplitude of temperature variation.



Concurrent measurement of temperatures above and below several of the ponds may yield important information about attenuation of bypass effects; this information may lead to conclusions about benefit on the basis of the number of beaver dams downstream of the bypass location. If beaver dams are found to strongly attenuate the bypass effect, bypass flows may yield little benefit in Ranch Creek. This type of study can be run concurrently with a longitudinal series of sites in Ranch Creek or the Fraser.

Data Analysis

The daily temperature data from streams generally conform to a sinusoidal time-series[3]. By fitting such a model to the data, several important characteristics can be determined at each site for each day or for a period of several days. Useful

[3] See, for example, G McRae & CJ Edwards. 1994. Thermal characteristics of Wisconsin headwater streams occupied by beaver: Implications for brook trout habitat. Transactions of the American Fisheries Society 123: 641-656.

characteristics include the minimum, maximum, amplitude, and time of maximum (phase shift); time above an arbitrary threshold or heating rate at a specific time of day3 might also be useful. Daily characteristics are used to define changes in temperature caused by transit through a reach or a beaver pond.

Bypass flows are turned on for a period of days and then turned off for a comparable period. The appropriate number of days depends on travel time through the reach, as explained previously. Daily temperature characteristics and the changes observed across reaches or the beaver ponds can then be segregated into groups according to whether flows were bypassed or not. The statistical approach for analyzing the data will depend on how much these characteristics change at individual sites over the course of the VPP, but could be as simple as a t-test. Results of the statistical test will help determine the longitudinal persistence of the bypass effect on stream temperature.

It is reasonable to expect that the daily amplitude and the daily maximum will be decreased when flow is bypassed; increasing the flow increases water depth, which means that heat transfers are occurring in a larger volume. The effect of bypass flows on stream temperature will dissipate over time whether the water is flowing in Ranch Creek or the Fraser River.