RECOMMENDATIONS FOR AN ADAPTIVE BEAVER MANAGEMENT PLAN

FOR PARK CITY MUNICIPAL CORPORATION

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EXECUTIVE SUMMARY

This report was sub-contracted by the Park City Municipal Corporation (PCMC) to provide recommendations for adoption of a Beaver Management Plan. **The primary purpose of this report is to advise the PCMC on how best to manage beaver populations on city controlled lands to balance the habitat needs of beaver and associated wildlife, the aesthetic value that wildlife offers Park City residents and visitors, and the need to protect public and private property and resources.** The report defines the areas of management concern as all waterways within city limits, and helps focus those management concerns by mapping actual beaver dam densities and predicted maximum dam densities with a capacity model. As of 2013, an estimated 51 beaver dams were mapped in Park City and the current capacity of the drainage network is estimated at roughly 86 dams. Using this context, the entire drainage 40+ kilometer network was classified in terms of four categories that relate directly to different management scenarios:

1. *Non-Beaver Bearing Water Courses* – Water courses not thought to be capable of supporting beaver and are not considered 'at risk' of experiencing beaver damage to private or public property and infrastructure.
2. *Beaver Conservation Zone Water Courses* – Water courses capable of supporting healthy beaver colonies and dam building at frequent (5-15 dams /kilometer) or pervasive (15-40 dams/kilometer) densities.
3. *Living With Beaver Zone Water Courses* – These water courses are in areas where beaver activity has some potential to cause damage to infrastructure, but the impacts are minimal and/or easily mitigated with 'living with beaver' strategies.
4. *Nuisance Beaver Zone Water Courses* – These water courses may support beaver at low densities, but due to presence of sensitive infrastructure, these are areas where beaver are not encouraged. Living with beaver management actions may be taken. Virtually all areas within subdivisions and golf courses were mapped as nuisance beaver zones.

An adaptive management plan was proposed that includes a simple monitoring framework to guide decision making and management actions. The framework is flexible and easy for PCMC to evaluate and adjust periodically as needed to meet the plan objectives. Therein, two decision support trees help PCMC transparently document nuisance beaver problems, make a management decision, and take management actions. The plan encourages planning for the financial costs of mitigating for beaver activity. The plan encourages 'living with beaver' actions wherever feasible, that aim to mitigate flooding impacts or damage from undesirable harvest of trees and allow the beaver to remain in place. Past experience has shown that 'living with beaver' options are generally cheaper and simpler than traditional removal options. Where nuisance beaver activity cannot be mitigated, the plan explicitly allows for removal of beaver. Where possible, a live trapping and relocation strategy in cooperation and compliance with the Utah Division of Wildlife Resources is recommended when beaver removal is deemed necessary. Live-trapped beaver can be relocated within the State of Utah to areas where they are desirable for the ecosystem engineering and services they provide and to be used in Watershed Restoration efforts. Park City may wish to pursue restoration and conservation efforts within the 'Beaver Conservation Zone Water Courses' as beaver offer a dramatically cheaper form of stream restoration then traditional approaches.

BACKGROUND & PURPOSE

Over the past several years, there has been a growing appreciation in both the scientific community and the restoration and conservation communities about the importance of beaver as a keystone species in the long-term sustainable management of natural resources associated with riverine and riparian systems (DeVries *et al.*, 2012; Pollock *et al.*, 2012; Polvi and Wohl, 2013; Wohl, 2013). Beaver have actually been used as a conservation and restoration tool since the 1940's but their popularity as a conservation tool has grown dramatically in the past decade. The primary drivers for this interest have been i) the ever increasing price tags of stream restoration when beaver can do better for virtually free, ii) their ability to create complex and dynamic stream habitats – thought to be a hallmark of a healthy stream ecosystem, and iii) their ability to potentially treat much larger areas then originally For an overview of different 'partnering with beaver in restoration' strategies visit http://beaver.joewheaton.org.

Amongst the many reasons managers are turning to beaver for help are the ecosystem services provided by their dam building activities (Hood, 2011). This list below from Bird *et al.* (2011) highlights many of the feedbacks and services from beaver dam building:

- Beaver dams slow snowmelt runoff, which
    - Extends summertime stream flow
    - Restores perennial flow to some streams
- Beaver dams create ponds, which
    - Maintain and create wetlands
    - Provide nurseries for salmonids and other native fish
    - Provide critically<needed amphibian habitat
    - Increase habitat for small mammals, cavity-nesting birds (using drowned trees)
    - Contribute to establishment of deep-rooted sedges, rushes, native hydric grasses, and woody riparian vegetation
    - Improve downstream water quality by trapping and storing sediment
    - Create mesic meadows in sediment behind abandoned dams
- Water enters groundwater upstream of, beside, and downstream of dams, which
    - Sub-irrigates the valley
    - Allows water to re-enter creeks/streams downstream as cooler seeps, which
        - is critically important to cold<water fish, e.g., salmonids
        - reduces evaporative loss
    - Expands and restores riparian vegetation, which
        - Shades creeks/streams, which
            - Reduces water temperature
            - Provides hiding cover for fish
        - Buffers banks against erosion during high flows
        - Provides critical fish and wildlife habitat
    - Restores and expands deep-rooted riparian vegetation, which
        - Increases bank integrity during high flows
        - Increases critical wildlife habitat
- A series of beaver dams can function as "speed bumps" during high water flows, which
    - Spreads water outward on the floodplain
    - Recharges groundwater near stream

    - Locally reduces flood force and gouging
    - Increases stream complexity, including creation of backwater and pools
    - Expands the presence of water for riparian plant communities
    - Prevents or reduces headcutting
- Beaver dams capture sediment, which
    - Raises incised streambeds, reconnecting them with their
    - Provides soil for mesic meadows
    - Reduces losses of sediment from the forest and into water facilities
    - Reduces the conversion of complex stream and riparian habitat to straightened ditches
    - Heals headcuts
- • Beaver increase large woody debris in creeks, due to
    - Tree cutting
    - Dam building
    - Existing dams and their remnants which
        - Increase complexity of streams
        - Increase bank integrity during high<flow
        - Increase habitat for fish, otter, amphibians, and other aquatic species
        - Reduce expense of human construction/maintenance/repair of instream structures or placement of large, woody debris in streams

Despite the benefits of beaver in stream ecosystems, many misconceptions still exist (Kemp *et al.*, 2012), and there is no question that beaver can be a destructive nuisance in built environments. Beavers can clog culverts, interfere with diversions, flood public and private infrastructure, and harvest trees we may not want them to. In the built-environment, these impacts simply cannot go unaddressed. The real question this report seeks to address is what alternatives are there to the traditional lethal control of beaver and removal of their dams? Significant annual maintenance and repair costs can be incurred in performing these traditional beaver management activities.

To help develop realistic goals for managing beaver in nuisance situations or as a restoration partner, it is critical to understand some of their biology and behavior. *Castor canadensis* (North American beaver) can inhabit water courses throughout North America and their only habitat needs are wood and water. Beaver only build dams on water-courses that don't meet their habitat requirements of maintaining underwater entrances to their lodges and having deep enough water to swim in and escape predators quickly. In areas, like Park City, that experience cold winters and the potential of water freezing over, beaver build dams to serve two primary additional functions. First they want to maintain water deep enough that it does not freeze all the way through and they can exit their lodges. Secondarily, they collect large winter food-caches on the bottom of their ponds in the fall consisting of the branches and limbs of hardwoods (e.g. aspen, willow and cottonwoods). These food caches provide them with food to sustain them through the long winter and the deep water of a pond ensures they can access this supply throughout the winter from their lodges. A basic understanding of these habitat requirements and what it takes to maintain them in a dynamic stream environment in which flows can vary widely is critical in developing realistic expectations of what to expect from beaver.

Present beaver habitat in Park City is highly fragmented and degraded. Historically, Park City would like have been littered with between 700 and 1100 beaver dams and dam densities ranging from 10 to 30 dams per kilometer. The combination of historic mining operations, drainage of beaver meadows and wetlands for agriculture, and more recent extensive development of golf courses, ski resorts, residential and commercial areas has had major impacts on the drainage network. The network is probably only 20-30% of its former length with many of the channels having been filled and removed, put in pipes, and combined to form larger drainage ditches. The vast

majority of riparian areas have been decimated and left devoid of anything approaching the former extent of natural riparian vegetation. There are nearly 70 man-made ponds and reservoirs within city limits, providing a significant amount of surface storage and further fragmenting the connectivity of the drainage network. These Most of the over 40 kilometers of remaining water courses are heavily altered, channelized armored.

The primary purpose of this report is to advise the Park City Municipal Corporation on how best to manage beaver populations within city limits to best balance the habitat needs of beaver and associated wildlife, the aesthetic value that wildlife offers Park City residents and visitors, and the need to protect public and private property and resources. The recommendations herein are based on a mix of i) experiences managing beaver populations elsewhere, ii) relevant state and federal policies surrounding beaver, iii) what has been learnt in the practice of stream and river restoration efforts that 'partner with beaver', and iv) the latest scholarly research on beaver and their impacts (positive and negative) on hydrology, geomorphology, hydraulics, local ecosystems, and the built environment. The issues surrounding the management of beaver are well understood and the methods for living with beaver mitigations, and partnering with beaver in restoration agents are reaching maturity. Even though many municipalities and agencies are still stuck in traditional lethal removal approaches to beaver management, the State of Utah has one of the most progressive Beaver Management Plans in the country that paves the way for a more holistic and sustainable approach to beaver management. PCMC has an opportunity to lead by example and be one of the first municipalities in the country to leave outdated perceptions behind and move forward with a beaver management plan that dovetails with the State of Utah's and can work better.

AREAS OF MANAGEMENT CONCERN

The areas of management concern are all within the PCMC's city limits (Figure 1). Within that area, this management plan is only concerned with those areas where beaver activity actually does or could occur. Notionally, beaver could potentially use any waterway or water body. However, the primary management concern is associated with beaver dam building activity, which is limited to the waterways. All the waterways within Park City drain to two creeks: Silver Creek (HUC8: 16020101) to the east, and McLeod Creek (HUC8: 16020102) to the west. Both creeks are part of the Weber River Watershed (HUC6: 16020), which eventually drains to Salt Lake. Silver Creek is fed by Deer Valley Creek, Ontario Canyon, Empire Canyon and Walker & Webster Gulch, all of which drain parts of the Deer Valley and Park City ski resorts. McLeod Creek only drains the Park City Ski Resort and some hills to the north of town, and its primary tributaries are Thaynes Canyon and Iron Canyon.

To facilitate planning, a good GIS drainage network layer was needed for the waterways. Both the FEMA floodway waterway layers and NHD drainage network layers are derived off coarse-resolution 10 to 30 m digital elevation models and are highly inaccurate within Park City limits. As such, a new drainage network was hand-digitized from 50 cm resolution aerial imagery flown in 2012 using a 1 meter resolution LiDAR digital elevation model and the existing waterway layers as context. The derived waterway layer is shown in Figure 1, and is the basis for all subsequent analyses reported here. Within PCMC City Limits and city owned open space areas, there are roughly 40 kilometers of waterways that are potential areas of management concern. Over 2.5 kilometers of the 40 km flow in culverts and/or beneath bridges (roughly 80 crossings).

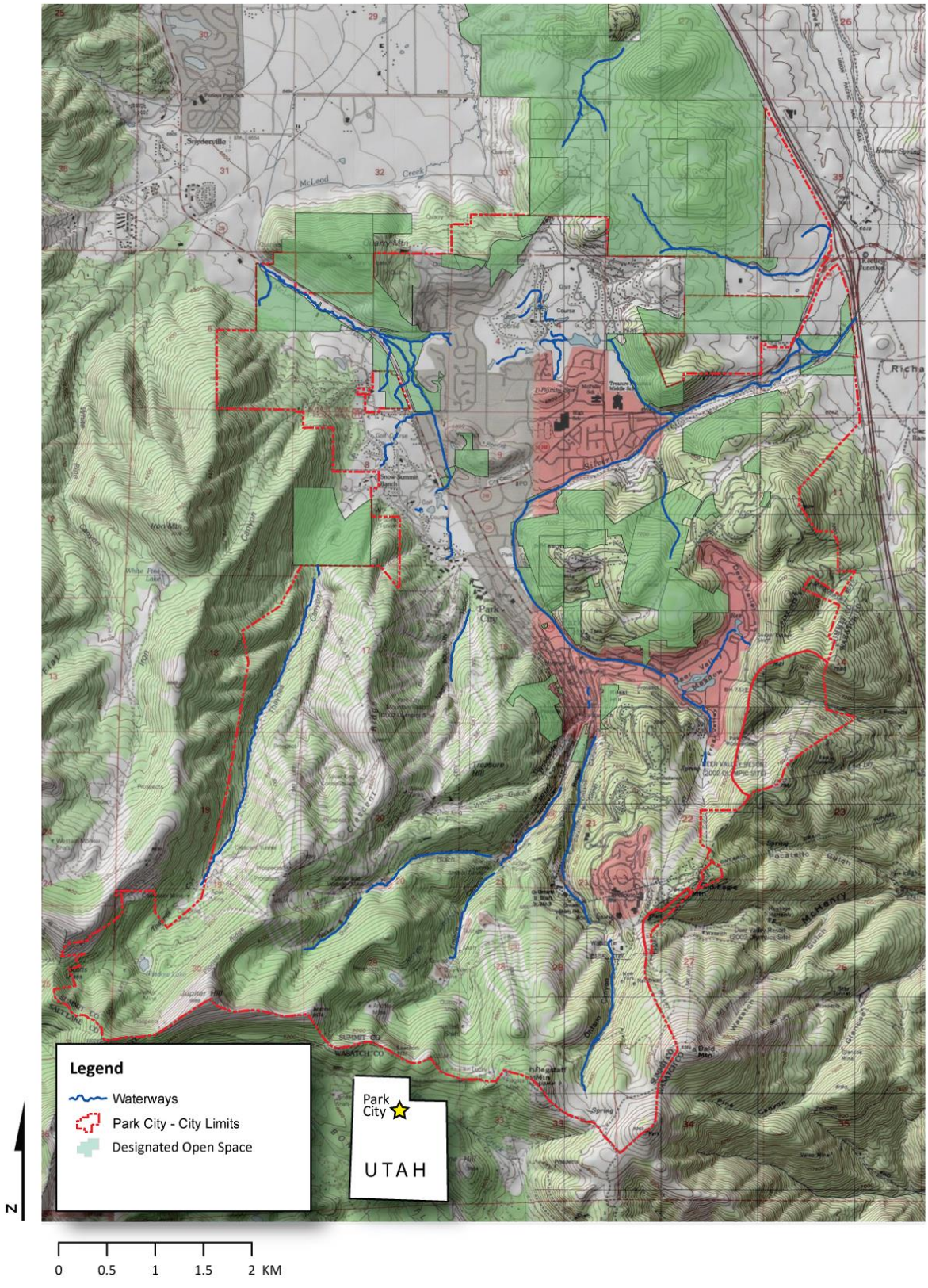

Figure 1 – Vicinity map of waterways of potential management concern and which of those intersect PCMC owned properties. USGS 7.5 Minute Quadrangles and 30 m NED hillshade shown for context.

IDENTIFICATION OF SUITABLE BEAVER HABITAT WITHIN PARK CITY LIMITS

The next step in considering potential beaver management concerns is to focus on the waterways that either currently are supporting beaver or have the capacity to support beaver in the future. Two primary lines of evidence were used: i) mapped locations of existing beaver dams and ii) a beaver dam building capacity model. The locations of beaver dams were mapped from a combination of a field visit in May of 2013, 2012 aerial photography, and information from PCMC staff. Figure 2 shows the location of roughly 51 beaver dams, which were mapped within the areas of management concern. 26 of these dams were mapped within the white inset box area on McLeod Creek and an unnamed tributary along Meadow Drive (Figure 2). The dam density along Meadow Drive is 17.6 dams/kilometer. 24 of the 26 dams in that area are on PCMC property designated as open space. The next highest concentration of dams was found along the lower portion of Silver Creek along Kearns Boulevard on the way out to Highway 40. Approximately 16 dams are located along this 2 kilometer stretch of Silver Creek, in a stretch of creek that is heavily impacted from mine tailing waste and confined on one side by a railroad grade and on the other side by a road prism.

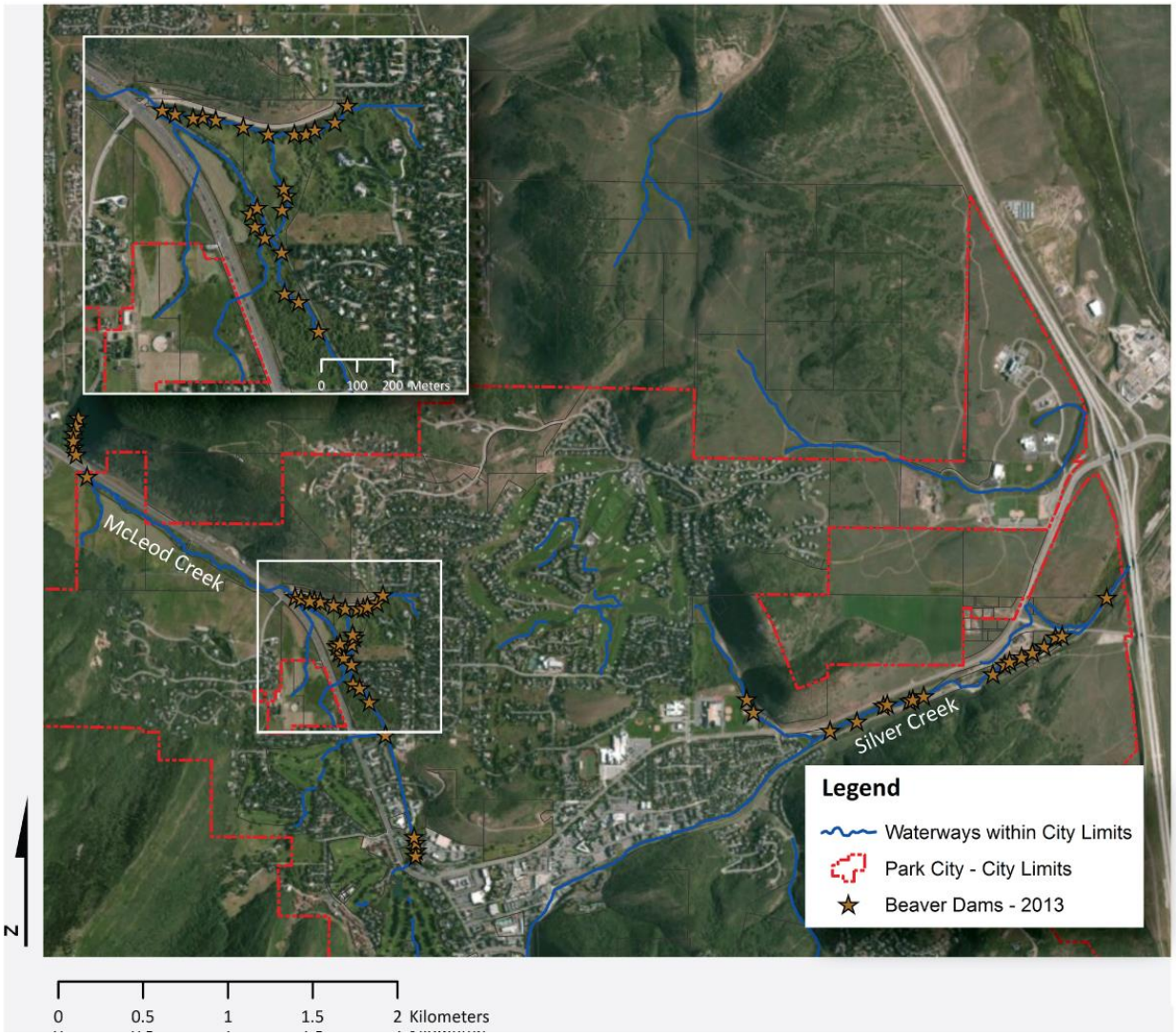

Figure 2 – Approximate inventory of beaver dams as of May 2013.

To estimate the existing capacity of the stream to support dam building activity by beaver, a beaver dam capacity model was used that is part of the BRAT (Beaver Restoration Assessment Tool – http://brat.joewheaton.org) developed by MacFarlane and Wheaton (2013). The model considers the role of existing vegetation (for dam building materials and forage), whether or not beaver dams can be built at baseflows, and the likelihood of beaver dams to withstand high flows to develop an estimate of maximum dam density (in dams per kilometer) for every reach of a drainage network. A mix of aerial imagery and LANDFIRE was used to assess existing vegetation.

Results of the BRAT analysis are shown in Figure 3 and summarized in Table 1. Roughly 56% of the waterways within PCMC city limits are predicted as not capable of supporting beaver dam building activity. Most of these are highly modified water courses and/or dry for much of the year (i.e. intermittent flow). Owing primarily to a lack of extensive riparian vegetation and adjacent forests (e.g. aspen groves) to support colony expansion, there are no waterways predicted as capable of supporting 'pervasive' dam building with densities greater than 16 dams/km. Nearly 35% of the drainage network is predicted as capable of supporting 'occasional' beaver dams at densities of 1-4 dams/km. A mere 3.5 kilometers is predicted as being able to support frequent dam densities (i.e. 5 -15 dams/km), and this is exclusively in McLeod Creek. Virtually all the waterways in Deer Valley and Park City Ski Resort have been so heavily altered they are predicted as incapable of supporting beaver.

Using the BRAT dam capacity estimates, a range of estimates of the maximum number of beaver dams the waterways within PCMC city limits are likely to be able to support given current conditions (Table 1). The best estimate is that a maximum of 71 dams could be supported at full capacity, but it is possible as many as 110 dams might be built given current resources. Given the development within PCMC, it is unlikely the system would ever realize this full capacity estimate. The primary factors that could increase this capacity over time, would be the restoration and/or expansion of riparian corridors, and the primary thing that would limit this capacity would be the further degradation of riparian areas (particularly in the 3.5 kilometers predicted as capable of supporting frequent dams).

Table 1 – Summary Statistics of BRAT Capcity Model Results and Estimates.

BRAT Existing Capacity Category:	Length of Stream (kilometers)	% of Drainage Network	Lower Capacity Estimate	Meidan Capacity Estimate	Upper Capacity Estimate
None	22.8	56%	0	0	0
Occasoinal (1-4 dams/km)	14.4	35%	14	36	58
Frequent (5-15 dams/km)	3.5	9%	18	35	53
Pervasive (16-40 dams/km)	0.0	0%	0	0	0
Total	**40.7**	**100%**	**32**	**71**	**110**

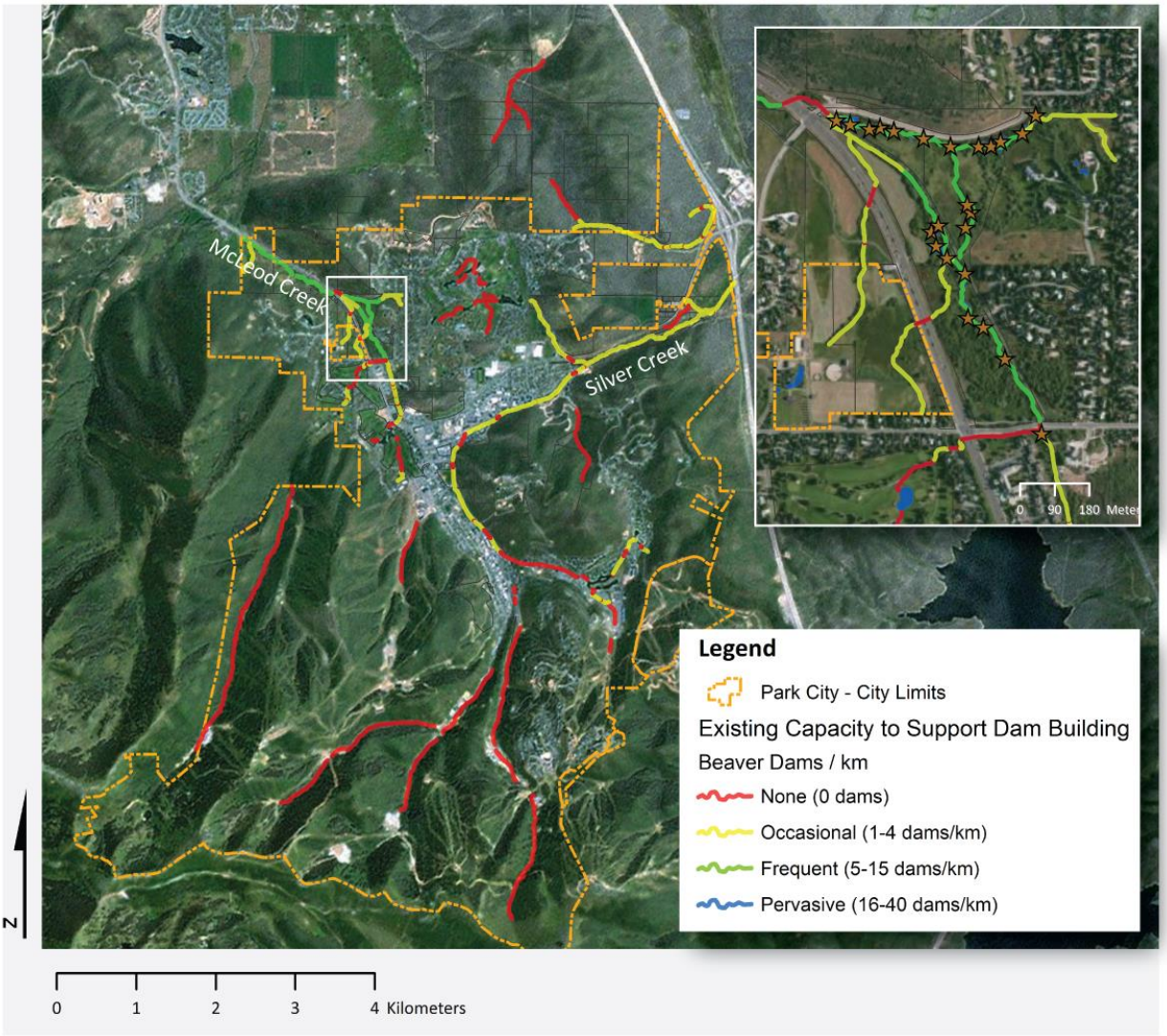

Figure 3 – Results of Existing Capacity to Support Dam Building Model.

CLASSIFICATION OF AREAS OF POTENTIAL MANAGEMENT CONCERN

To facilitate a clear and transparent decision-making process associated with the evaluation of stream reaches within PCMC city limits experiencing beaver activity, we have classified four types of streams. Each stream type carries with it an explicit and distinct set of potential management decisions and actions. PCMC staff can adjust this classification at any time to address changing conditions and it is recommended that the classification itself is reviewed periodically for is relevance (e.g. every 5 to 10 years). The four types of water-courses are:

- *Non-Beaver Bearing Water Courses* – Water courses not thought to be capable of supporting beaver and are not considered 'at risk' of experiencing beaver damage to private or public property and infrastructure. As beaver generally need perennial waterways (Allen, 1983), all ditches, swales, canals and ephemeral water courses are not considered part of the area of management concern.
- *Beaver Conservation Zone Water Courses* – Water courses capable of supporting healthy beaver colonies and dam building at frequent (5-15 dams /kilometer) or pervasive (15-40 dams/kilometer) densities.

These water courses are in PCMC-owned areas zoned as open-space zones and/or in designated conservation easements. Accordingly, they have significant aesthetic and recreational potential (§Development of a Restoration Plan). These water courses do not necessarily currently have beaver in them.

- *Living With Beaver Zone Water Courses* – These water courses are in areas where beaver activity has some potential to cause damage to infrastructure, but the impacts are minimal and/or easily mitigated with 'living with beaver' strategies. These areas were generally mapped in areas that are predicted by BRAT to support frequent dams, but are in close enough proximity to sensitive infrastructure that they conflicts could arise.
- *Nuisance Beaver Zone Water Courses* – These water courses may support beaver at low densities, but due to presence of sensitive infrastructure, these are areas where beaver are not encouraged. Living with beaver management actions may be taken. Virtually all areas within subdivisions and golf courses were mapped as nuisance beaver zones.

The mapping in Figure 4 shows the recommended classification[1] of the waterways in PCMC city limits according to the above criteria. Table 2 summarizes the recommended classification in terms of length and percentages. Also in Table 2, the actual number of beaver dams found in each waterway type are shown. Of the 51 beaver dams mapped in PCMC city limits, 42 are found in areas recommended for designation as 'Living with Beaver Zones', 5 were found in 'Nuisance Beaver Zones', and 4 were found in the recommended 'Beaver Conservation Zones'. Based on a comparison with the BRAT-estimated capacity modeling, the 'Living with Beaver Zones' are at or over their capacity and currently are home to 81% of the beaver dams. Thus, major expansion of beaver activity in these areas is unlikely primarily because of woody building material limitations. By contrast, the areas flagged as 'Beaver Conservation Zones' are under seeded and are estimated to be only at 17% of their potential capacity. This is important as it means that there is currently capacity in these areas (3.3 potential kilometers) to potentially receive relocated nuisance beavers from 'Nuisance Beaver Zones'. Conversely, these may be areas that the dispersing beaver from the 'Living with Beaver Zones' disperse in to.

PCMC may opt to switch some 'Living with Beaver Zones' to 'Nuisance Beaver Zones' to highlight areas that may be more sensitive. Given that the classification is based on the physical capacity of the waterways to support beaver dam building activities, it is not anticipated that major changes will be required. However, PCMC staff should feel free to update these maps in an adaptive fashion as part of the 'adjustment' phases of the §Proposed Adaptive Management Plan.

[1] Note that the resolution of mapping delineation of water courses should be considered at +/- 30 to 60 m. Boundaries between reach types are not necessarily always sharp, and may be gradual.

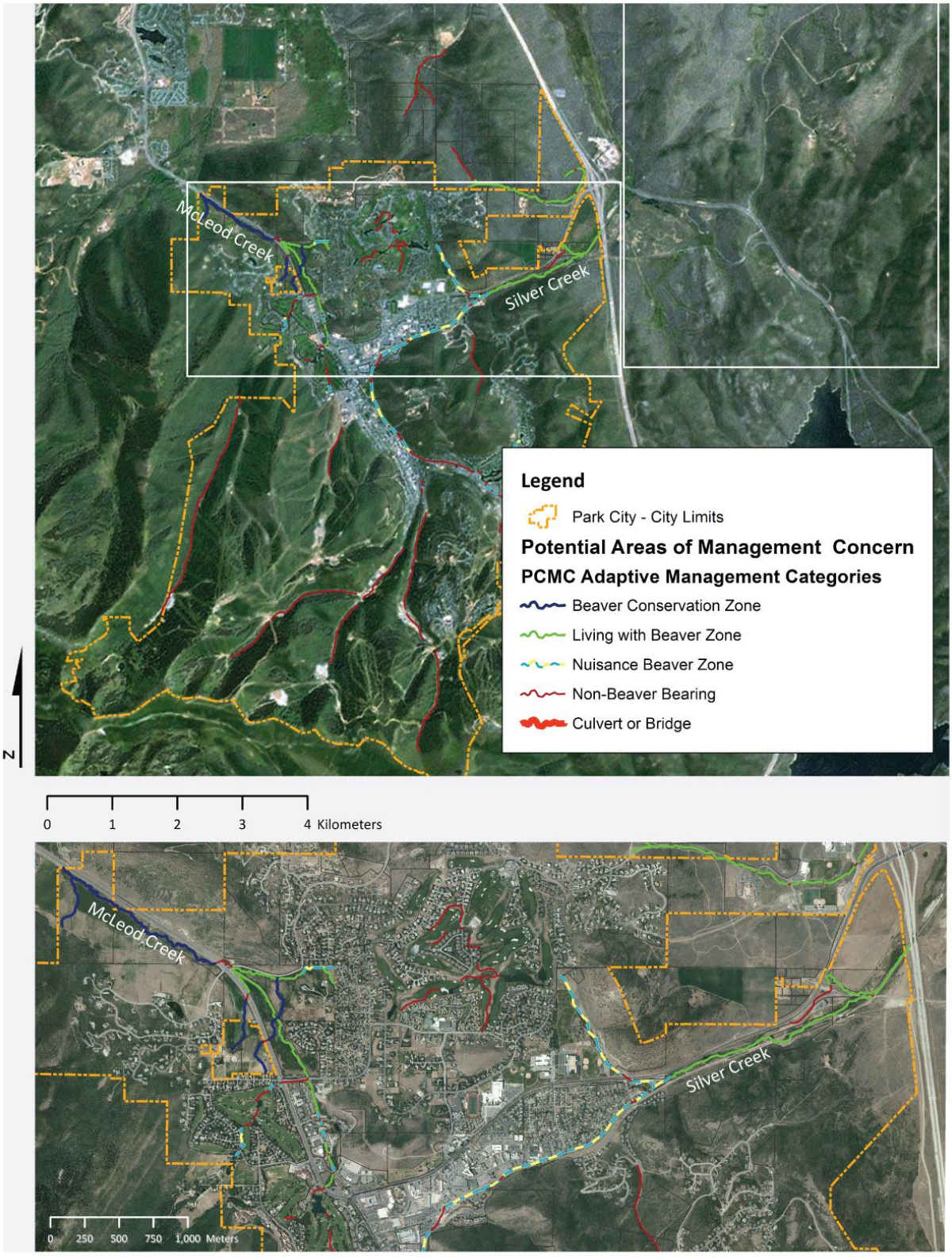

Figure 4 – Recommended classification or 'zoning' of waterways according to how beaver could be managed to balance beaver needs and PCMC's need to protect private and public property and infrastructure.

Table 2 – Basic Summary Statistics of Waterway Classification.

	Length of Stream (kilometers)	BRAT Estimated Dam Capacity	2013 Actual Estimates	2013 Average Dam Densities (dams/km)	% of Drainage Network	% of Beaver Dams	2013 % of Estimated Capacity
Non-Beaver Bearing	22.8	0	0	0.0	56%	0%	0%
Nuisance Beaver Zone	5.7	15	5	0.9	14%	10%	33%
Living with Beaver Zone	8.9	33	42	4.7	22%	82%	127%
Beaver Conservation Zone	3.3	23	4	1.2	8%	8%	17%
Total	**40.7**	**71**	**51**	**6.8**	**100%**	**100%**	**72%**

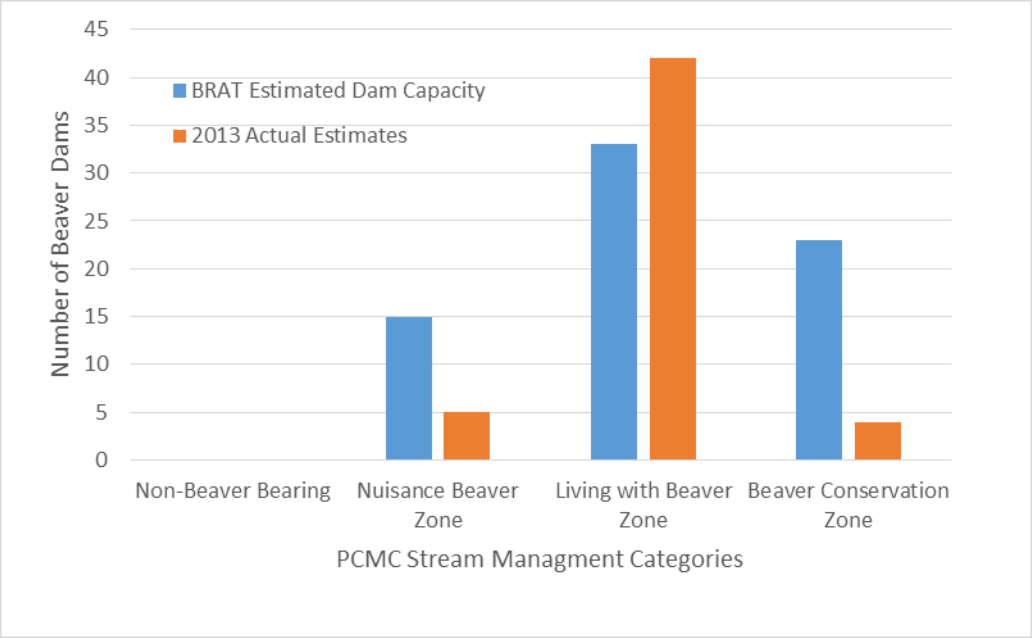

Figure 5 – Comparison of BRAT estimated dam capacity and 2013 mapping of beaver dams. This shows that 'Living with Beaver Zones' are roughly at capacity and 'Nuisance Beaver Zones' and 'Beaver Conservation Zones' are both under seeded relative to what they could support. However, nuisance beaver zones are not areas where PCMC will want to encourage beaver activity, but beaver conservation zones could be.

PROPOSED ADAPTIVE MANAGEMENT PLAN

Unlike many management actions, managing public resources and infrastructure in the presence of beaver activity is not a simple task, in as far as the chosen management actions will not always produce the desired results. Much like predicting the weather, it is straight forward to predict the range of possible beaver responses to different management strategies, but it is impossible to predict exactly what beaver will do every time. Generally, short term predictions are easy, seasonal predictions provide reasonable boundaries on expectation management, but precise long term predictions are tricky. Accurate predictions of multiple plausible outcomes can be made most the time, but a precise prediction of a single outcome is not possible all the time. Similarly, it is naive to expect that a simple response like lethal trapping will produce the desired response and permanently put an end to all nuisance activities by beaver. Any management actions regarding beaver will require ongoing maintenance and evaluation. This situation lends itself well to adoption of a flexible adaptive management plan as opposed to a rigid and entirely reactive management approach (Holling, 1978; Walters, 1997).

The proposed PCMC Beaver Adaptive Management Plan is outlined in Figure 6 below.

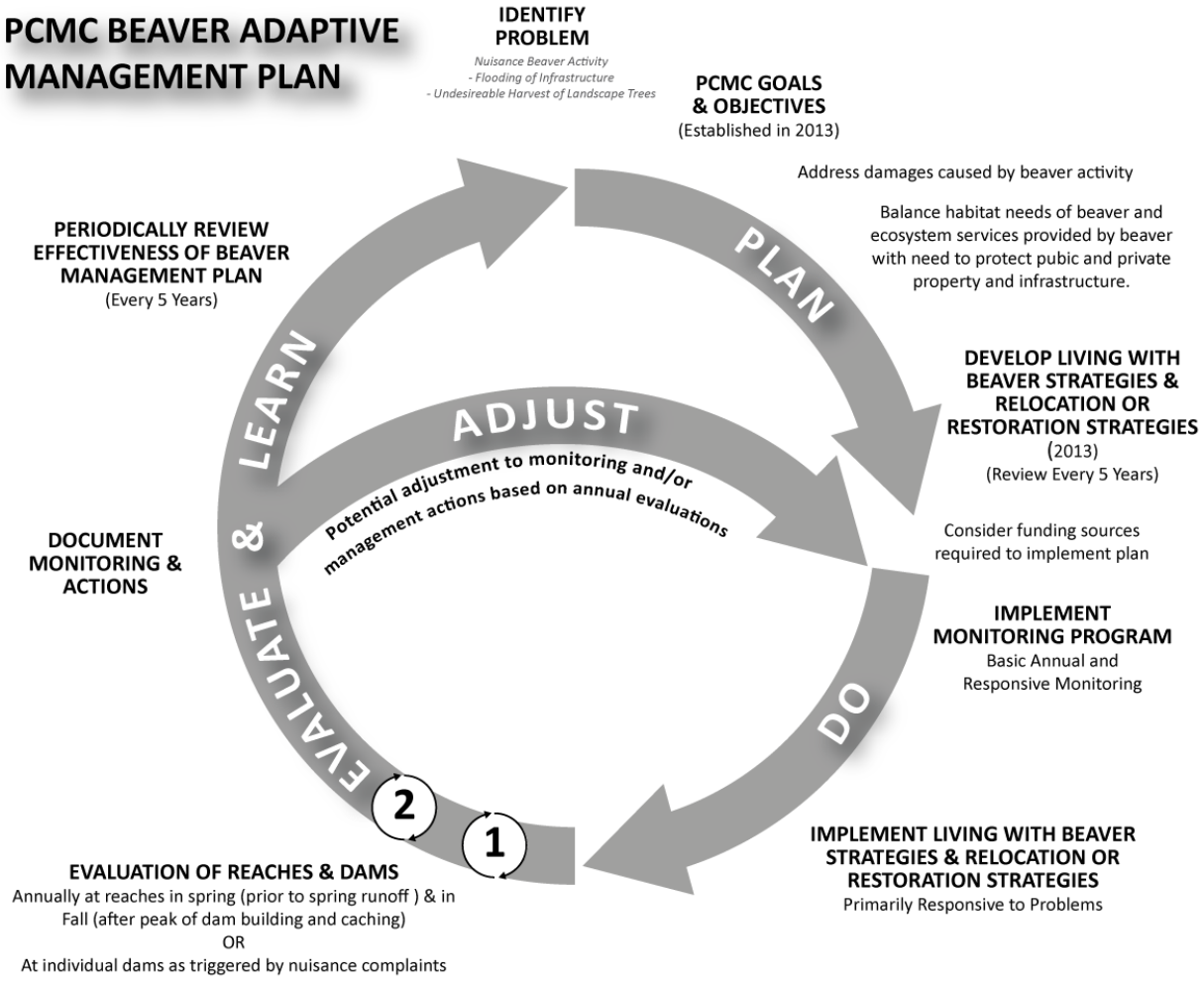

Figure 6 – Schematic overview of proposed PCMC Beaver Adaptive Management Plan.

The plan's goal is to balance the habitat needs of beaver and ecosystems provided by beaver with the need to protect public and private property and infrastructure. The plan is designed to afford PCMC staff flexibility and the ability to employ common sense in how they respond to problems and concerns as they arise. Whereas Figure 6 outlines the overall elements of the proposed PCMC Beaver Adaptive Management Plan, the next two sub-sections outline the Monitoring Actions and Typical Management Responses. The sub-sections leverage the context provided by both the §Identification of Suitable Beaver Habitat within Park City Limits and the §Classification of Areas of Potential Management Concern.

MONITORING ACTIONS

An essential element of any effective adaptive management plan is the inclusion of a monitoring component that allows the evaluation of ongoing management actions (Walters, 1997). It is recommended that PCMC formalize its current actions with respect to managing nuisance beaver and mitigating their impacts with a simple monitoring scheme. A rapid-assessment monitoring program is outlined that allows PCMC to transparently document situations and its actions through time. The recommended monitoring involves simply walking the *Living with Beaver Zone Water Courses* and the *Nuisance Beaver Zone Water Courses* twice a year or evaluating specific potential problem beaver dams in response to specific complaints or concerns. The next two sub-sections outline in a simple decision support system the recommended evaluation questions and management responses the city follow. As the plan is 'adaptive', PCMC can always adjust and improve the decision support system to better meet its objectives and account for circumstances unforeseen at the time this plan was drafted.

MONITORING WATER COURSES WITH BEAVER ACTIVITY

It is reccommended that the *Living with Beaver Zone Water Courses* and the *Nuisance Beaver Zone Water Courses* are monitored twice a year. Typically, spring runoff will pose the biggest potential flooding impacts from beaver dams; whereas most dam building activity takes place mid to late autumn in preparation for the winter. Accordingly, monitoring sometime in May- June prior to the peak of spring runoff, and monitoring sometime in October to November during the peak of beaver winter preparations are recommended. The monitoring frequency and timing can be adjusted and/or augmented by PCMC to meet specific concerns as they arise. The initial monitoring evaluation is of an entire water course segment and PCMC should break the water course into logical segment lengths that coincide with breaks in stream conditions or land ownership and subsequently management responses (e.g. along the reach boundaries designated by type in Figure 4).

For each segment, PCMC personnel should record whether or not evidence of beaver activity is present. If beaver activity is present, the first step in the decision support system is to identify if and where beaver activity is taking place and record its location in a GIS (Figure 7). Beaver activity in a *Living with Beaver Zone Water Courses* should be evaluated to determine if the dam building or harvest of woody materials by beaver is causing harm. For example, if flooding of critical infrastructure is taking place or undesired harvesting of woody trees is taking place, these would be considered harm. If the beaver activity is determined to be causing harm, the beaver activity should be evaluated individually using the procedures outlined in the next section (§

Evaluation of Individual Potential Problem Dams). By contrast, if the beaver activity is deemed not to be causing harm, and no new risks are apparent the beaver and any dams present should simply be left alone. If new or future risks are present, the beaver activity should be evaluated individually using the procedures outlined in the next section (§

Evaluation of Individual Potential Problem Dams).

If in the first step, the location where beaver activity is taking place is in a *Nuisance Beaver Zone Water Courses*, PCMC staff should still evaluate whether the beaver activity is causing harm. This includes not only the threats of flooding and undesirable harvest of trees, but other indirect impacts (e.g. mosquitos). If the beaver activity is determined not to be a threat, the beaver and/or their dams should be left alone. If beaver activity is or has significant potential to cause harm, staff should evaluate whether or not 'Living with Beaver' strategies (see § Living with Beaver Actions) are appropriate. If such actions would or might be effective, the beaver activity should be evaluated individually at each dam using the procedures outlined in the next section (§

Evaluation of Individual Potential Problem Dams). If staff determine that 'Living with Beaver' strategies are unlikely to be effective, or they have been attempted in the past and proven ineffective at this locality, or the risks are simply too high, removal of nuisance beavers is recommended. Removal of beaver can only be done in consultation with UDWR staff and under their guidelines. See §Removal, Live Trapping & Relocation Options for explanation.

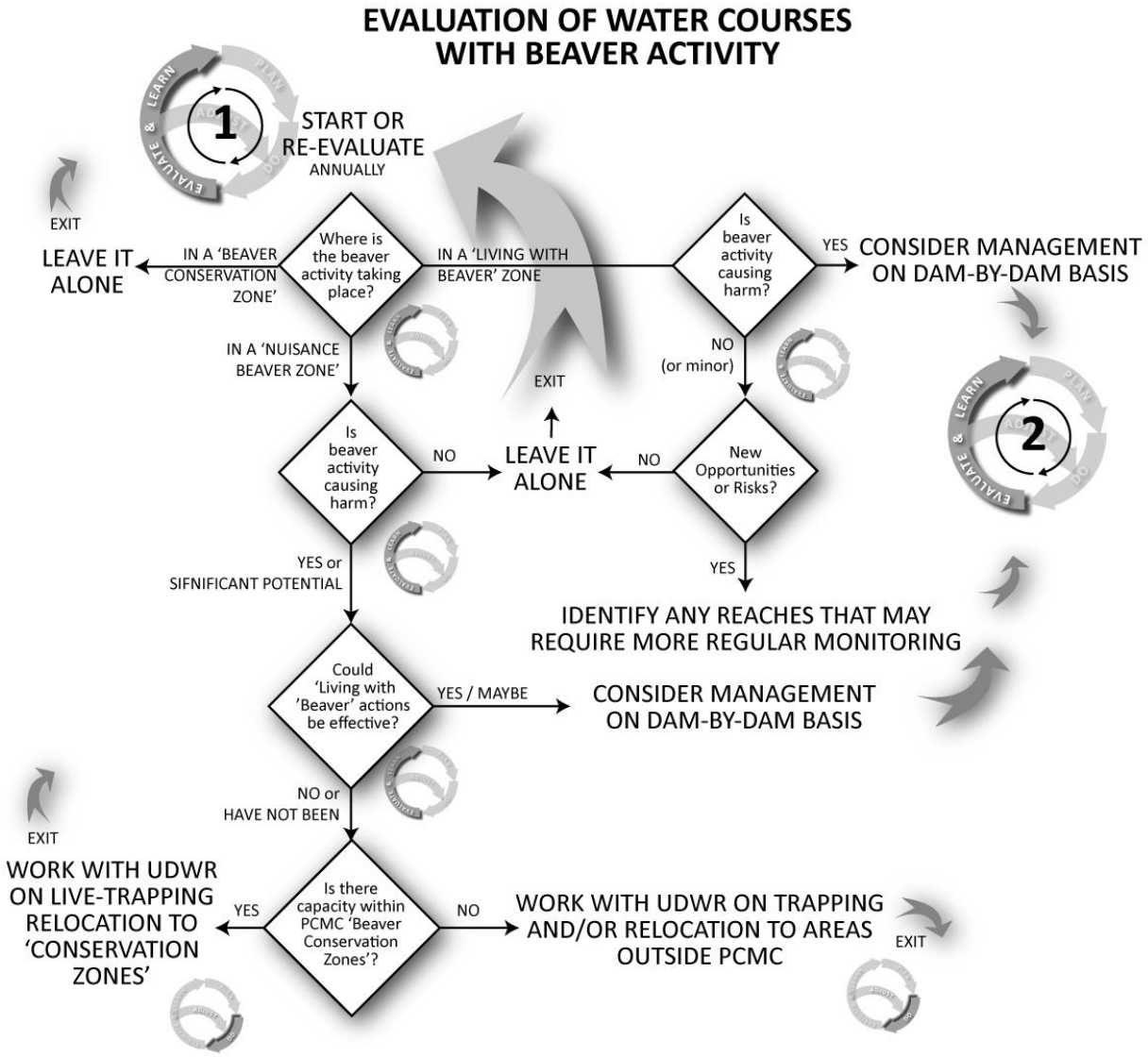

Figure 7 – Flow chart diagramming monitoring evaluation of water courses with beaver activity. This decision tree highlights decisions and evaluations in the diamonds, and recommended management actions in all CAPITALS. The approximate step in the adaptive management loop is shown next to each decision and action from Figure 6, and the evaluation of management actions at individual dams area (2) are shown in Figure 8.

EVALUATION OF INDIVIDUAL POTENTIAL PROBLEM DAMS

Once a beaver dam or activity (e.g. harvesting, or culvert plugging) has been identified as a potential problem in either the monitoring of water courses (see §Monitoring Water Courses with Beaver Activity) or has been reported by a concerned party, it is reccommended that PCMC staff engage in the evaluation processes outlined in Figure 8.

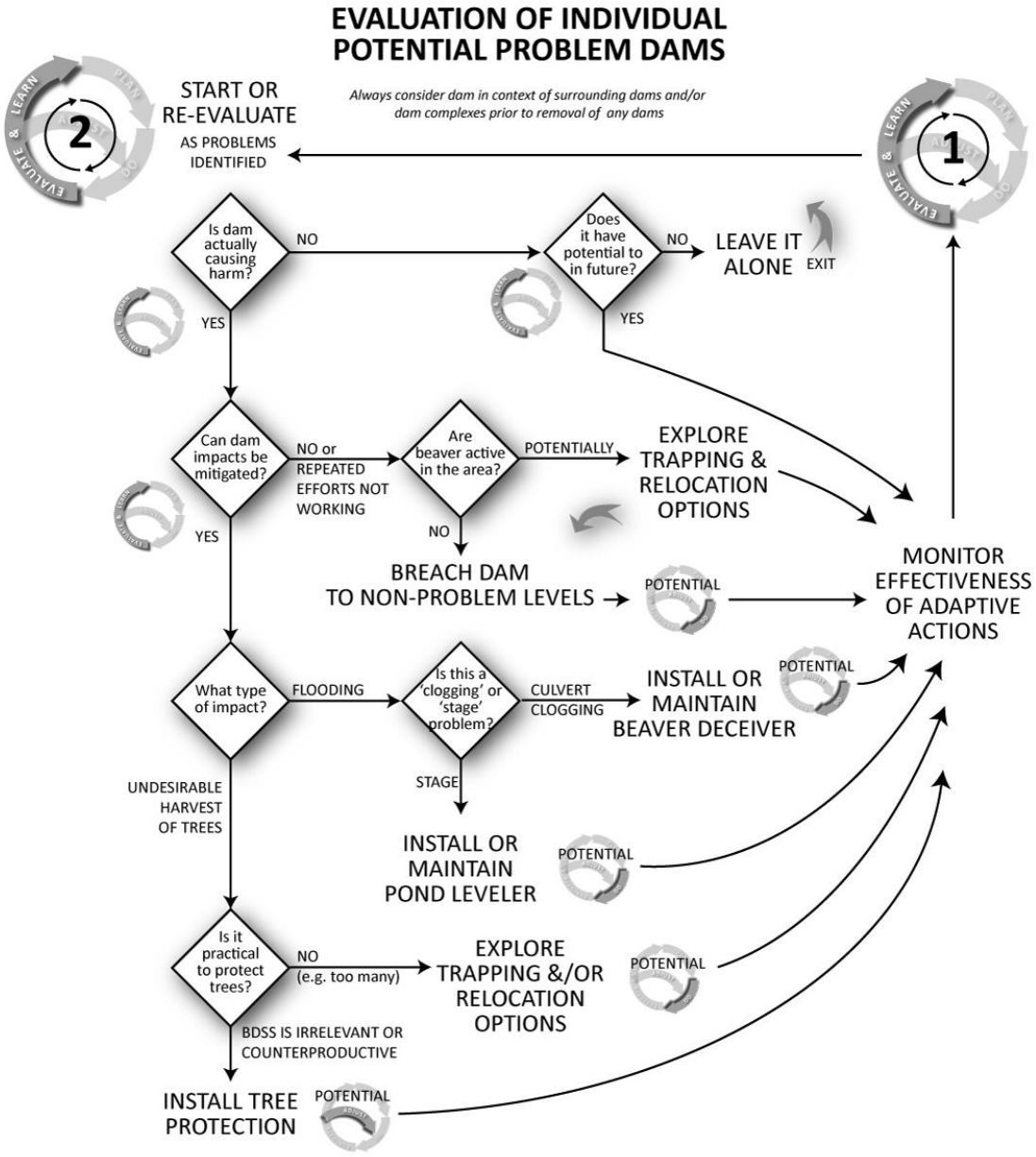

Figure 8 - Flow chart diagramming monitoring evaluation of potential problem beaver activity. This decision tree highlights decisions and evaluations in the diamonds, and recommended management actions in all CAPITALS. The approximate step in the adaptive management loop is shown next to each decision and action from Figure 6, and the evaluation of management actions at individual dams area (2) are shown in Figure 8.

Regardless of the management action decided when following this process, the assessments, decisions and action should be documented and the location recorded in a GIS. This simple data stream will help provide context and inform future decisions, and allow PCMC to periodically review the effectiveness of management decisions.

The starting point for the evaluation of individual potential problem dams involves a decision by PCMC staff about whether the dam is actually causing harm. In many instances, particularly nuisance complaint calls, the problem is more of a perceived problem or potential future threat. In these instances potential future concerns can be considered and the dam flagged for follow up evaluations at an interval that makes sense for the circumstances, or the problems can be dismissed. If the dam is determined to be causing impacts, the next decision is to assess whether or not those impacts can be mitigated. If they cannot, or have been repeated multiple times and different approaches attempted, the next question is if beaver are still actively using the dams. This question is important because sometimes the flooding impacts might persist well after the beaver activity in the area has ceased. In these situations, the dam can be breached to drain it to a stage height that the pond stage height is no longer causing flooding issues. Given the ecosystem services associated with beaver ponds, it is recommended that inactive problem dams are breached and not completely blown out or removed (this also much less labor intensive). If beaver choose to recolonize the area, they can build a brand new dam in a matter of days and/or plug a breached dams in a similar time frame. Complete dam removal is extra labor, and is generally not effective as a deterrent. If there are problem dams that cannot be mitigated (i.e. multiple attempts have been made or threatened infrastructure is too sensitive), live trapping and relocation options should be explored with UDWR (see §Removal, Live Trapping & Relocation Options).

If PCMC staff determine that the impacts from a dam causing harm can be mitigated, the next question is whether this is a flooding impact or an undesirable harvest of trees. If multiple impacts are present, multiple pathways through the decision tree can be taken (Figure 8). These decisions all fall under the §Living with Beaver Actions. If the problem is the undesirable harvest of trees, PCMC need to determine whether or not it is practical to install tree protection (§Install Fencing Around Sensitive Trees), otherwise live trapping and relocation options should be explored (§Removal, Live Trapping & Relocation Options). If the problems are flooding related, PCMC staff need to identify whether this is a culvert clogging issue or a pond stage height issue. In the case of culvert clogging, a beaver deceiver may need to be installed or maintain (§Install Beaver DECEIVER to Prevent Culvert Clogging). Beaver deceivers always require maintenance (especially during high flows), and it strongly recommended that this is used only when beaver are actually physically plugging the culvert, and not just when their dams or activity are in close proximity to a culvert. More regular 'check-ups' on the status of beaver dams next to culverts is much cheaper, less labor intensive and aesthetically pleasing then a beaver deceiver that requires continual maintenance. In the event that the flooding issue is because the stage height of the dams are too high, a pond leveling device can be installed or maintained. PCMC has extensive experience using pond levelers and these can be an effective means of mitigating a flooding threat. They do require maintenance (particularly during high flows), but it is generally much less than that of a beaver deceiver. PCMC should consider when beaver dams are no longer actively maintained by beaver, what to do with pond levelers. They may be perceived as an eye-sore and the piping and hardware should not just be left in the stream as litter. It may make sense when beaver activity has not been present for multiple years to decommission old pond levelers that are no longer necessary, and leave the dams with a breach at the stage height the pond-leveler was set to.

TYPICAL MANAGEMENT RESPONSES

LIVING WITH BEAVER ACTIONS

There are a variety of 'living with beaver' actions that can be used to mitigate flooding and harvest activities of beaver, some of which PCMC has been using since 2011. These options are summarized succinctly in Tippie (2010) in a non-technical manner, but are more thoroughly documented in Mike Callahan's Beaver Solutions website (http://www.beaversolutions.com/). Below we summarize each of the 'living with beaver' actions recommended in this plan. Park City already has in-house expertise in the construction of beaver pond levelers.

BREACH DAM

When a dam is no longer actively maintained by beaver, but still poses flooding problems, partial breaching (i.e. notching) of the dam is recommended over full removal. Notching the dam allows the water level to be managed, but still retains some of the habitat benefits and ecosystem services of beaver ponds. Breaching is not recommended in situations where beaver are still actively maintaining a dam as they can repair a breach in a matter of hours.

INSTALL POND LEVELER TO CONTROL STAGE

In situations where beaver are active and causing flooding problems, pond levelers can be an effective means to control pond stage heights and flooding, while allowing beaver to continue to build their dams higher and inhabit the area.

PCMC staff already have experience with installing and maintaining roughly 15-20 pond levelers. The cost of installing and maintaining such devices should be considered during the planning and adjustment phases of the adaptive management cycle (Figure 6). A pond leveler *typically* takes about a half day of labor and with materials may be estimated to cost somewhere between $600 and $1000. Maintenance will primarily be limited to labor costs, likely take 30 to 60 minutes per structure and should be checked regularly during spring runoff and/or periods of intense rainfall.

See http://www.beaversolutions.com/pond_control.asp for more information.

INSTALL BEAVER DECEIVER TO PREVENT CULVERT CLOGGING

In situations where beaver are clogging culverts, beaver deceivers can be used as a deterrent. As mentioned above, beaver deceivers require regular maintenance, and should only be used when the threat of clogging has major consequences and/or in response to actual clogging. Again, the cost of installing and maintaining such devices should be considered during the planning and adjustment phases of the adaptive management cycle (Figure 6).

See http://www.beaversolutions.com/culvert_clear_systems.asp for more information.

INSTALL FENCING AROUND SENSITIVE TREES

With the right fencing methods, heavy gauge wire mesh can be used around the trunks of trees and effectively deter beaver from harvesting sensitive trees. Sensitive trees will have to be considered on a case-by-case basis, but may include those if felled could cause damage to infrastructure or block roads and trails, as well as landscaping trees. When fencing, extra care should be taken not to install the wire mesh to tightly as to girdle and potentially kill the tree. Fencing should be checked for effectiveness annually and potentially removed and/or replaced every three to five years.

See http://www.beaversolutions.com/tree_protection.asp for more information.

REMOVAL, LIVE TRAPPING & RELOCATION OPTIONS

Removal of beaver includes both the lethal trapping and live trapping. Live trapping and relocation can only be done in consultation with UDWR staff and under their guidelines (2010). To effectively mitigate impacts of nuisance beaver where beaver are to be removed, an attempt should be made to trap all the nuisance beaver present at the time in the impacted segment of the water course. It should be noted that when pursuing removal options, effectively trapping all nuisance beaver is easy to say but difficult to achieve in practice. Even if done successfully, dispersing beaver from nearby can simply take their place within a short amount of time. For these reasons, lethal removal is suggested as a last resort. It is strongly recommended that PCMC work with UDWR to live trap and relocate nuisance beaver either to *Beaver Conservation Zone Water Courses* within PCMC city limits, or to areas UDWR has identified where the beaver can be used for watershed restoration efforts in accordance with UDWR's (2010) Utah Beaver Management Plan. Lethal trapping of nuisance beaver is an option, but if not done for sport and/or use of their pelts, is a waste of both a fur-bearing resource and a potentially useful ecosystem engineer who could help in restoration efforts. However, lethal trapping is admittedly the standard of practice across most municipalities.

It is recommended that PCMC foster a strong working relationships with the UDWR Biologists in the Central Region so that if and when removal options are to be pursued, the workflow is simple. Although UDWR has a relatively new and progressive Beaver Management Plan, not all districts or UDWR biologists have experience with the live-trapping and removal portions of the plan, nor are destination sites and procedures for timely removal and relocation necessarily in place. Thus, when a nuisance situation is encountered, and removal is identified as the option, without proper planning live trapping is not always possible. If a partnership is established prior to a removal need, some of these arrangements can be made ahead of time and relocation sites established.

The time of year for live trapping should also be considered. Beaver dam-building activity and harvest will be minimal to non-existent over the winter months and impacts should also be minimal. Relocation should be avoided during the winter. Beaver are central-place forages and areas with hard winters they stockpile woody vegetation on the bottom of their ponds in late fall to provide a winter food cache to sustain them through the winter. Food caching is typically done from September to mid-November and if beaver are to be relocated during the Fall, they should be afforded at least one to two weeks prior to the onset of winter to establish dams and build up food caches. Live trapping and relocation during the late spring and summer months is appropriate, provided the areas they are being relocated to have adequate habitat and woody material available for forage and dam building. Many practitioners have had success provide fresh aspen and willow cuttings at release sites and beaver quickly feed on these and incorporate them into their dams.

It is recommended that PCMC further explore the use of Beaver as a Restoration tool on the downstream portions of McLeod Creek within PCMC's open space areas. Some of these areas are currently under-seeded relative to their capacity estimates and could make good destinations for nuisance beaver elsewhere in Park City. A plan would need to be developed with UDWR biologists to permit and allow this. For PCMC, there are many potential advantages to having an 'in-house' destination for local nuisance beaver (see §Recommend Future Work), but from a purely logistical perspective this could alleviate timing problems and avoid unnecessary delays. Little research exists on how likely relocated nuisance beaver are to attempt to return to their original dams when they are not relocated that far away. Beaver can easily move about over the entire distance of all of PCMC's waterways within a day or two. For this reason, PCMC may wish to coordinate with UDWR to tag relocated beavers for potential later re-identification.

The contact details for UDWR Central Region are:

> Central Region
> 1115 N Main St., Springville, UT 84663
> Phone: 801-491-5678

If PCMC is unsuccessful at finding helpful contacts within the Central Region, they can try contacting Kent 'Sorno' Sorenson (kentsorenson@utah.gov) from the Northern Region and he may be able to help make the right contacts.

In addition, PCMC may find it advantageous to develop a relationship with a professional licensed beaver trapper. According to the 'Utah Furbearer Annual Report' (Bernales *et al.*, 2012), there were no licensed beaver trappers operating in Summit County in 2011-2012. However, trappers in nearby Wasatch, Morgan and Weber counties had 18, 7 and 14 licensed beaver trappers respectively. Beaver are considered a fur-bearer and licensed trappers are allowed to trap and harvest beaver typically from late September to mid-April every year in designated areas. Beaver pelts sold for only $15.61 in 2012, so there is little financial incentive to trap, and these individuals are primarily trapping for the sporting and recreational opportunities. However, some of the professional trappers are highly skilled and knowledgeable about beaver and may be willing to help PCMC in either live or lethal trapping. Rates will vary, but roughly $400 to $500 to set traps and maintain them, and then roughly $400=$500 per animal have been suggested. Due to the potential risks of trapping causing unintentional harm to domesticated animals (e.g. dogs) PCMC may prefer to work with licensed professionals who carry their own liability insurance.

Live trapping and relocation guidelines are available from a variety of sources, but regardless of the guidelines followed all live trapping and relocation must be done in accordance with UDWR's Beaver Management Plan.

For more information see:

- (Tippie, 2010)
- Beaver Solutions: http://www.beaversolutions.com/trapping_beavers.asp
- The Methow Beaver Project: http://www.methowconservancy.org/beaver_project.html

RECOMMEND FUTURE WORK

The proposed adaptive beaver management plan presented was designed to address the current problems Park City faced in dealing with impacts from nuisance beaver, and balancing that with a public desire to protect and promote wildlife. Although the motivating problem for PCMC to consider a beaver adaptive management plan

were problems caused by nuisance beaver, beaver also provide PCMC with many positive benefits. The plan does leave scope for the city to capitalize on restoration opportunities using beaver. Other opportunities to capitalize on the fact that beaver are re-establishing their presence in Park City also exist. These include providing public wildlife viewing areas through expanded trail access and outreach through interpretive signage. Given the increasing prevalence of positive stories about beaver in the news (see: http://beaver.joewheaton.org/beaver-links/interesting-websites-on-beaver#TOC-Beavers-in-the-News) PCMC's new plan could be used for positive public relations. These and other areas the city might consider expanding its future efforts with respect to beaver management are briefly outlined in the subsections below.

DEVELOPMENT OF A RESTORATION PLAN

Although Park City has many aesthetically pleasing waterways, from hydrologic, geomorphic and ecological perspective they are largely in extremely poor condition. Given the highly degraded and artificial condition of the majority of the Park City drainage network, stream restoration using beaver may be a cost-effective way for the city to pursue restoration actions and improve the ecological integrity on some of these streams and waterways. Typical stream restoration costs are on average about $80,000 per kilometer and the city may be able to pursue restoration actions for virtually no cost, by employing beaver. Realistic expectations and a restoration plan addressing the feasibility of using beaver at different stages of restoration and recovery would need to be developed. However, given that only 14% of the drainage network was mapped as 'Beaver Conservation Areas' and they are currently underutilized by beaver (at 18% of estimated capacity), not only might these areas be potentially improved, but they could also be expanded.

The low-hanging fruit restoration opportunities lie in the downstream portions of McLeod Creek, where the city owns the land, there are not major threats to infrastructure, it is already designated as open space, and the highway and bike paths past these areas provide an excellent opportunity to showcase the work.

TRAIL ACCESS, INTERPRETIVE SIGNAGE & PUBLIC VIEWING AREAS

Park city already has one of the most impressive and extensive trail networks in the world (PCMC, 2008). All of the areas that make sense for 'living with beaver' strategies and all of the 'beaver conservation' zones, already are paralleled or intersected by trails. The general public (inclusive of locals and tourists) enjoy watching beaver in habitats that they are constantly reshaping and modifying. The trail network in and around these areas could be expanded slightly to really showcase the role beaver are playing in improving Park City's waterways and point out the challenges they pose to sustainably managing the co-existence of humans and wildlife. A boardwalk that helped visitors peer out into the heart of some of these areas from a respectful distance could become a destination and/or centerpiece of the McLeod Creek trail system.

DEVELOPMENT OF MONITORING APP

Researchers at Utah State University's Ecogeomorphology and Topographic Analysis Lab (http://etal.joewheaton.org) have developed a variety of monitoring apps for smart phones and tablets, which can sync to spatially explicit central databases. It may make sense to codify the decision support trees of the proposed adaptive management plan and make it easy to document the monitoring process and record additional information (e.g. geotagged voice, video and photo notes) through time. These data streams could be uploaded in real-time to a secure, cloud hosted server and web application that provided PCMC with a decision support system

to document their monitoring and management actions and choose what and if these data streams are shared with the general public.

PARTICIPATION IN STATE-WIDE CITIZEN SCIENTIST BEAVER MONITORING

Researchers at Utah State University's Ecogeomorphology and Topographic Analysis Lab (http://etal.joewheaton.org) have partnered with the Water Quality Extension's Water Watch program and are launching a state-wide citizen scientist beaver monitoring program. This allows interested citizens to adopt a reach of stream of interest to them and perform beaver activity surveys. The program has built in redundancies to allow for quality assurance/quality control checks and many of the data collected are similar to the data streams suggested in this monitoring plan. The city might be able to redirect the energy and enthusiasm of concerned citizens worried about beaver into collecting data that may help PCMC in tracking beaver activity. It might also be an effective outreach and public relations tool to raise awareness of the PCMC Adaptive Beaver Management Plan and build support.

CONSIDERATION OF ANNUAL COST OF MONITORING & MAINTENANCE ACTIVITIES

Although it is outside the scope of this report to tabulate and estimate annual cost and maintenance activities, PCMC staff may consider comparing costs of implementing the proposed Adaptive Beaver Management Plan to traditional maintenance actions such as lethal control and dam removal. It might be helpful to add to the database a section on cost to track the economic impact of complying with this new plan. Therein, the benefits of ecosystem services could also be quantified (e.g. Buckley *et al.*, 2011), so a true cost-benefit analysis could be undertaken.

CONCLUSIONS

In response to PCMC's need and desire to balance the habitat needs of beaver and associated wildlife, the aesthetic value that wildlife offers Park City residents and visitors, and the need to protect public and private property and resources, an Adaptive Beaver Management Plan has been proposed. Implicit within this plan is a recognition that beaver provide an array of ecosystem services and benefits, while at the same time they can be a nuisance that causes serious damage to private and public infrastructure. The plan provides specific decision support by framing the right questions in the right contexts to help PCMC make transparent decisions about how best to balance these competing needs. The plan is informed by the most recent science on beaver management and restoration and state-of-the-art assessment tools to help quantify and map the location of existing beaver dams and the capacity of Park City's waterways to support them. Not every challenge beaver will pose is necessarily considered in this comprehensive plan, but the adaptive nature of the plan provides specific mechanisms for PCMC staff to adjust the plan as needed and make common-sense solutions to problems as they arise. Finally, the plan is in keeping with the sustainability agenda of PCMC and the ideas put forth in the Vision Park City planning exercises.

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