Memorandum
McMurdo Gulch Reclamation Template

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Purpose

A reclamation plan for McMurdo Gulch, a major tributary to Cherry Creek in the upper watershed, was developed in 2010 and implemented in 2011 under the sponsorship of the Cherry Creek Basin Water Quality Authority and the Town of Castle Rock. Although relatively undeveloped at the time of the study, there are significant plans for further build-out in the McMurdo Gulch watershed, making the timing of the reclamation plan advantageous to implement a proactive approach to protect the gulch and reduce sediment and nutrient loads into Cherry Creek in advance of increased stormwater runoff and degradation. It is believed that implementing measures to protect the gulch *before* the onset of severe erosion will be more cost effective and more favorable to downstream water quality than reacting *after* increased runoff has a chance to degrade the gulch.

This memorandum documents the unique design process undertaken for the reclamation of McMurdo Gulch in the three mile study reach to serve as a guide, or "template" for the reclamation of similar tributary streams in the upper Cherry Creek watershed.

The proactive reclamation plan for McMurdo Gulch is intended to preserve and protect the stream's environmental value prior to significant development in the watershed.

Elements of Reclamation Template

The primary elements of the McMurdo Gulch reclamation template are summarized below.

1. Start the process early. The reclamation process is intended to be proacti[illegible] best started prior to the onset of significant development and resulting stream erosion in the watershed. The objective of the approach is to implement improvements at the appropriate pace, in the appropriate locations, and of the appropriate type to stay ahead of problems while still stretching out capital expenditures over time.

2. Examine land use in the watershed. Obtain current aerial photography of the watershed to evaluate the locations and densities of existing developments. Examine planning documents and development plans that show projected land use and note the extents, representative imperviousness, and anticipated timing of development projects in the watershed. The larger the development, higher the average imperviousness, and quicker the anticipated build-out, the more the potential impact on downstream drainageways. Examine the information on soils, imperviousness, hydrology, hydraulics, and improvement recommendations in any existing master plans conducted for the watershed.

3. Inventory the stream. Undertake a field reconnaissance of the mainstem drainageway and major tributaries. Observe signs of instability (headcuts, bed degradation/ aggradation, bank erosion, constricted channel sections) and stability (lack of erosion, favorable cross sectional geometry, dense vegetation), presence of baseflows, soil conditions, stream bed material and sediment transport, longitudinal slope, vegetation characteristics, and any existing hydraulic structures such as dams, ponds, detention facilities, storm sewer outfalls, or grade control structures. Document conditions with field notes and photos. Locations of infrastructure such as roadway crossings and utilities should also be noted and any prior stream stabilization evaluations in existing master plans should be reviewed.

4. Develop plan to implement full-spectrum detention. Develop a plan to control peak discharges from developed areas to levels similar to or less than pre-development conditions over the whole spectrum of storm events -- from frequent small events to large flood-producing storms. At the least, it is anticipated that implementing full-spectrum detention in the watershed (and retrofitting existing detention facilities) to control runoff will reduce the level of improvements required for stream stabilization and will slow the pace of degradation such that funding resources can keep up with the required improvements. At best, it may be found that watershed-wide full-spectrum detention may eliminate the need for capital improvements in some stream reaches.

5. Develop proactive stream reclamation plan. Develop a plan to reinforce erosion “hot-spots” – the points along the stream that are weakest and most at risk for unraveling the stability of the whole system. Weak spots are determined both from observations of instability made during the field reconnaissance (Step 2) and from an evaluation of imposed and resisted shear stress from flood flow events. The goal of the first package of improvements is to address the areas of greatest concern and preserve the most stable stream features to reduce the level of risk for an entire reach at a far lower cost than undertaking an ultimate, conventional 100-year design. This is seen as a better long-term investment than, for the same dollars, applying a conventional design to just a portion of the stream length, perhaps over-securing one small section while leaving the remainder of the reach unprotected and vulnerable**.**

6. Conduct stream and watershed inventories annually. Track the developed area and imperviousness for each tributary subwatershed and the overall watershed on an annual basis. Inventory any planned or constructed developments in the watershed and assess the functionality of detention facilities in maintaining runoff rates at or below historic levels. Conduct annual stream inventories, assessing how the initial reinforcement improvements are functioning, how revegetation establishment is progressing, whether any signs off additional instability are noticed in reaches not addressed in the initial improvements, and the presence and magnitude of base flows. Prepare a brief report to document findings and present any recommendations for further improvements. Follow up on recommendations through design, funding, and implementation.

Each of these steps was applied to the McMurdo Gulch project, as discussed in the following sections.

Step 1. Start the Process Early

The concept of implementing a proactive stream stabilization approach on McMurdo Gulch was a collaborative idea of staff at the Town of Castle Rock and the Cherry Creek Basin Water Quality Authority. Pieter Van Ry with the Castle Rock Utilities Department and Bill Ruzzo, Technical Manager for the Authority, envisioned a study in the McMurdo Gulch watershed that would explore the benefits of assessing water quality issues and implementing improvements early enough to stay ahead of problems. Such a study, they reasoned, would be a good follow-up to the 2006 McMurdo Gulch Major Drainageway Master Plan and could serve as an example, or template, for proactive water quality implementation in the upper Cherry Creek watershed. The study was approved and begun in the summer of 2009.

Step 2. Examine Land Use in the Watershed

McMurdo Gulch is a western tributary to Cherry Creek that has a watershed area of 6.5 square miles. The McMurdo Gulch channel flows northward approximately 6.7 miles long from its southern headwaters to the confluence with Cherry Creek. Current aerial photography of the watershed was obtained and reviewed to determine the locations and densities of existing developments. Figure 1 shows the aerial coverage and identifies watershed and sub-watershed boundaries. At the time of the McMurdo Gulch study, only about one half square mile of the 6.5 square mile watershed was developed with any significant density. A small amount of commercial land use existed along Highway 86 in the southern, upstream end and two residential communities were being developed in the central and lower ends of the watershed. Castle Oaks is located on several tributary drainages that flow into McMurdo Gulch from the west in the central portion of the watershed and Liberty Village is located adjacent to mainstem McMurdo Gulch at the downstream end of the watershed. Canyons South is another large subdivision in the west-central portion of the watershed that is currently in the planning stages.

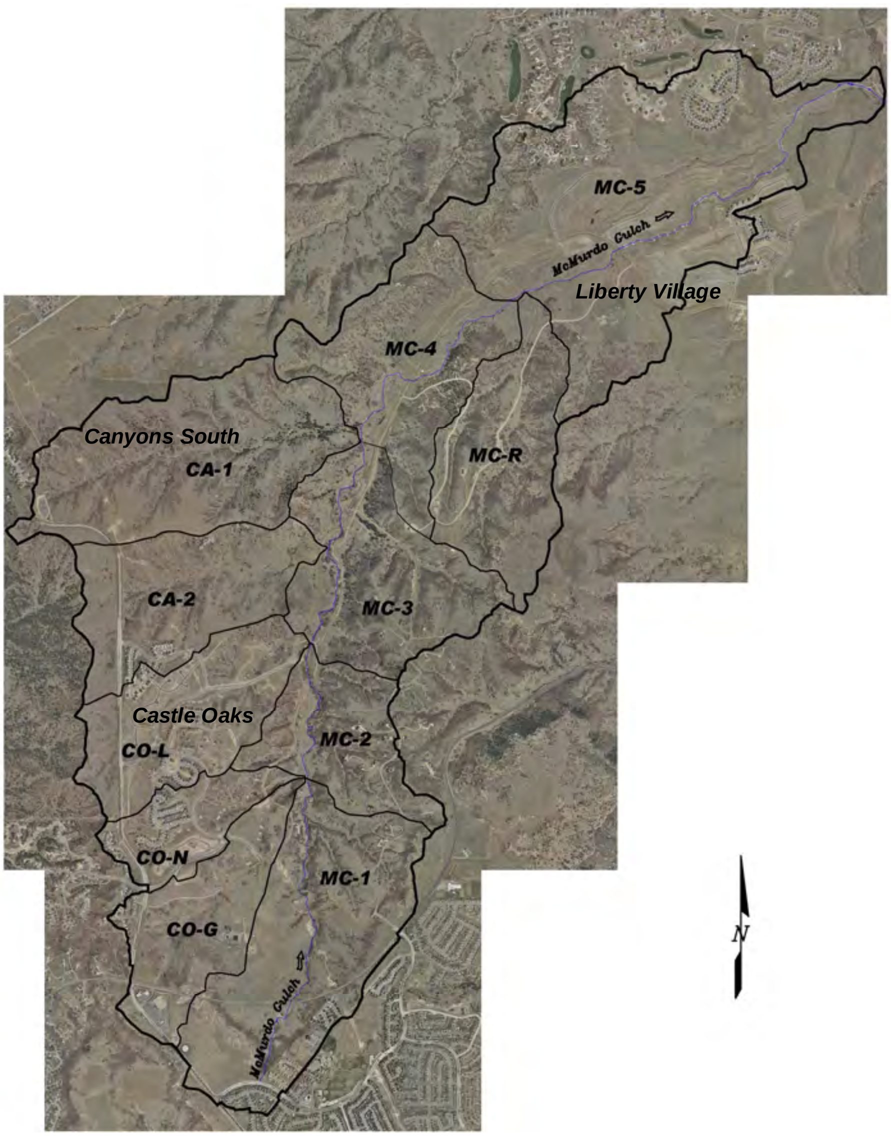

***Figure 1**. Recent aerial photography of McMurdo Gulch watershed showing the beginning stages of development.*

The aerial photography was evaluated to break existing land uses up into various categories, such as commercial uses, medium and high density residential, paved and gravel roadways, and open space. Representative imperviousness values were associated with these land uses and an overall estimate

Subwatershed	Area (acres)	Existing Imperviousness	Future Imperviousness
MC-1	503	9%	61%
MC-2	218	4%	33%
MC-3	360	3%	18%
MC-4	379	3%	10%
MC-5	893	8%	31%
MCR	312	3%	8%
CO-G	249	16%	34%
CO-L	298	18%	34%
CO-N	138	24%	34%
CA-1	489	3%	13%
CA-2	315	7%	18%
Overall	**4154**	**8%**	**27%**

Table 1. *Existing and future development imperviousness by sub-watershed.*

of imperviousness was made. The existing area-weighted impervious of the watershed is approximately 8 percent, as shown in Table 1. Although this is less than the threshold imperviousness of 10 percent that has been associated with the onset of impacts to natural stream ecology (Center for Watershed Protection, 2003), individual tributary areas have an existing imperviousness as high as 24 percent. Figure 2 shows that the effective imperviousness along mainstem McMurdo Gulch currently

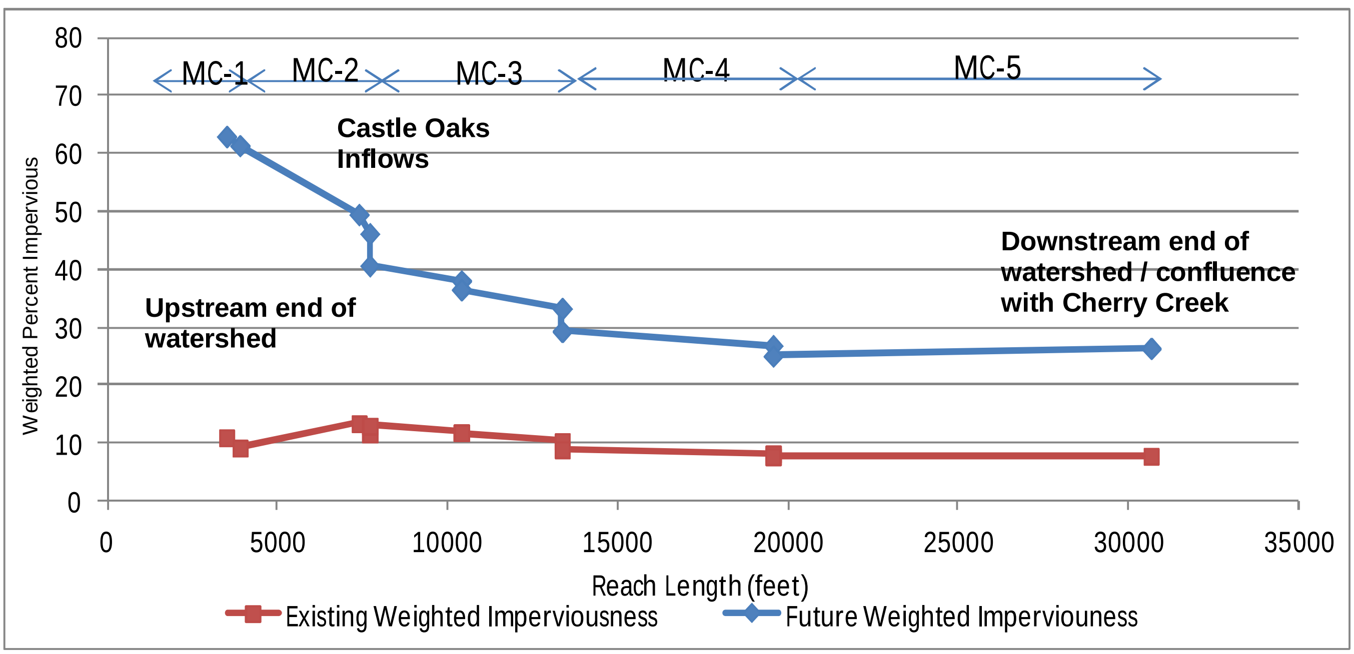

Figure 2. *Cumulative imperviousness draining into McMurdo Gulch for existing and future development conditions.*

reaches a high of 13 percent downstream of where Castle Oaks drains into the Gulch. This suggests that the timing of the McMurdo Gulch study, though proactive, is certainly not premature, since a portion of the Gulch already exceeds the 10 percent threshold of impacts. In future studies in other watersheds, it is recommended that similar "template" evaluations get started prior to reaching an imperviousness of 5 percent

Development plans for Castle Oaks and Liberty Village and planning documents for the remainder of the watershed were examined to understand projected land uses, representative imperviousness, and proximity to McMurdo Gulch and its tributaries. Substantial additional development is expected over time in the watershed within Castle Oaks, Liberty Village, and The Canyons South (locations shown on Figure 1). Also, a significant amount of higher density development is expected in the upper portion of the watershed. Figure 3 shows the anticipated areas of development in the McMurdo Gulch watershed.

The projected future imperviousness of the McMurdo Gulch watershed is approximately 27 percent, as indicated in Table 1. Figure 2 shows that the expected future imperviousness superimposed along mainstem McMurdo Gulch is as high as 61 percent. Since this is well over the 10 percent threshold where environmental impacts are likely, it is evident that mitigation measures will be necessary as the watershed continues to develop.

In addition to information on existing and projected imperviousness, available information on watershed topography, soils, vegetation, and hydrology needs to be reviewed and understood. For McMurdo Gulch, this information was compiled in the master planning document.

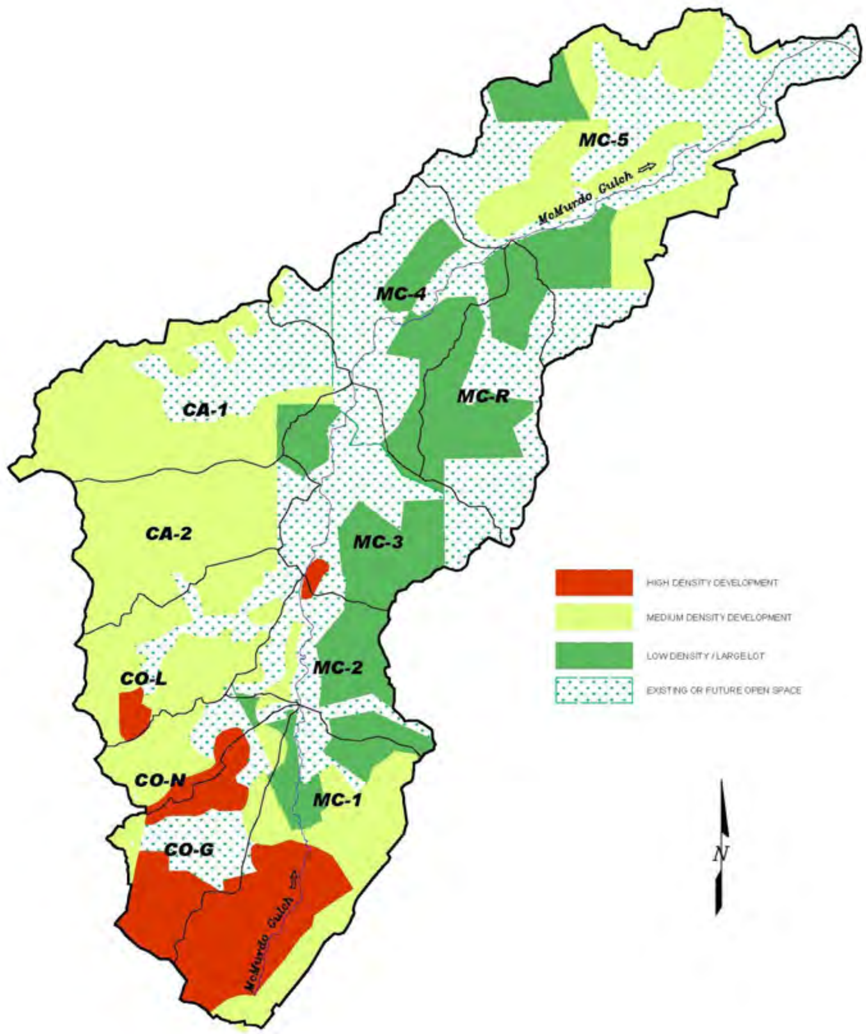

***Figure 3**. Projected future development in the McMurdo Gulch watershed..*

Assessing existing conditions along McMurdo Gulch..

Step 3. Inventory the Stream

A comprehensive field reconnaissance of McMurdo Gulch and several major tributaries was undertaken over several days. Conditions along the stream were observed and documented such as signs of instability (headcuts, bed degradation/ aggradation, bank erosion, constricted channel sections) and stability (lack of erosion, favorable cross sectional geometry, dense vegetation), presence of baseflows, soil conditions, stream bed material and sediment transport, longitudinal slope, vegetation characteristics, and any existing hydraulic structures such as dams, ponds, detention facilities, storm sewer outfalls, or grade control structures. Locations of infrastructure such as roadway crossings and utilities should also be noted.

The character of McMurdo Gulch varies dramatically over its length. The channel first becomes defined at a steep sandstone bluff just south of Highway 86 in the upper portion of the watershed. The Gulch is relatively dry in this area and is vegetated with upland grasses and shrubs. Several small dams constructed in the 1930's by the Civilian Conservation Corps (CCC) exist on mainstem McMurdo Gulch in the reach north of Highway 86. These facilities are not retaining any permanent pools upstream of the embankments, but would serve an informal detention function during runoff events.

The upper reach of McMurdo Gulch receiving runoff from Castle Oaks is characterized by wetter channel bottom conditions and lush riparian vegetation..

The reach downstream of the southern Castle Oaks tributary (draining subwatersheds CO-G and CO-N) has a wetter character. Here, a base flow is present, carried in a small micro-channel 1 to 2 feet wide and deep, and the adjacent channel benches are well-vegetated with lush grasses, sedges, and rushes. Willows, woody shrubs, and cottonwood trees are also present. The 20 to 40 foot wide channel bottom is flanked by steep (1:1 to 2:1), generally vegetated banks about 10 feet in height. Thus, although the floodplain channel is somewhat narrow and deep, the Gulch appears relatively stable and well vegetated. A number of small "nick points" of erosion are evident in various locations along the base flow channel.

The central, transitional portion of McMurdo Gulch is sandier with a larger low flow channel.

Moving further downstream, McMurdo Gulch enters a transition zone. Baseflows disappear and reappear frequently throughout the reach. Sandy soils and sediment deposition are evident, negatively impacting channel vegetation. In channel sections with base flows, the vegetation consists of thick wetland grasses, willows, and cottonwood trees. In sections where the baseflow runs below the surface, vegetation changes to sporadic upland grasses with some cottonwood and willow stands still present. The geometry of the main channel and floodway also change significantly over the course of the middle reach. The geometry changes from the narrow, deep section in the next upstream reach to a broad floodplain roughly 200 to 400 feet wide with a baseflow channel typically 20 to 40 feet wide and roughly 2 to 4 feet deep.

The lower reach of McMurdo Gulch becomes drier and sandier, with more sparse upland vegetation.

Base flows gradually disappear altogether and the vegetation transitions primarily to upland grass bunches and sporadic thickets of shrubs. Just downstream of the point where McMurdo Gulch crosses to the east side of Castle Oaks Drive, a barn yard has been constructed across the channel and some grading activities attempting to control the flow path are evident. Active erosion is evident in a number of locations in the lower, drier reaches of McMurdo Gulch. The sandy soils in the lower reaches are typified by sparser vegetation and are more susceptible to erosive forces. Also, in many areas along the sandy, wider channel, erosion has been caused by off-road vehicles crossing and running down the center of the channel.

It is important to protect the wetter, well vegetated reaches adjacent to Castle Oaks to try to preserve the environmental value of the area.

At the downstream end of the watershed, within the Liberty Village community, McMurdo Gulch has been channelized and stabilized in a trapezoidal section that has a bottom width of about 60 feet, a depth of approximately 8 feet, and large grouted boulder drop structures every 150 to 200 feet. No base flows are evident in this reach and channel vegetation consists primarily of upland grasses.

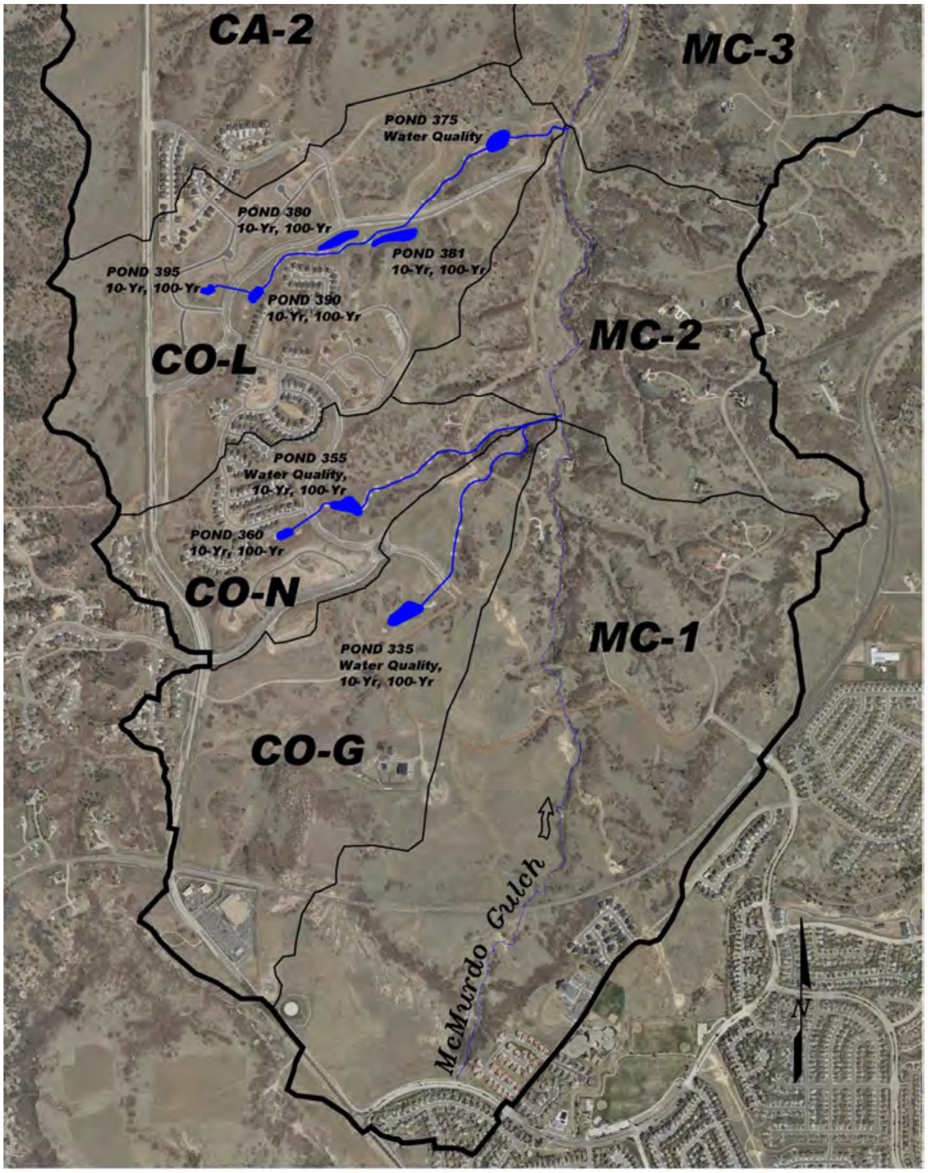

***Figure 4**. Eight existing detention facilities in Castle Oaks community were evaluated for retrofit improvements.*

Two reaches stand out as needing attention based on the inventory of conditions along the stream. First, the wetter, well vegetated reach adjacent to Castle Oaks needs to be protected and preserved, lest erosion and degradation from increased urban runoff ruin the valuable riparian resources along the stream. Second, active erosion in the drier, sandier reach downstream needs to be stabilized before it grows out of control in response to increased runoff.

Step 4. Develop Plan to Implement Full-spectrum Detention

A retrofit plan was evaluated to control peak discharges from developed areas to levels similar to or less than pre-development conditions over the whole spectrum of storm events -- from frequent small events to large flood-producing storms. At the least, it is anticipated that implementing full-spectrum detention in the watershed (and retrofitting existing detention facilities) to control runoff will reduce the level of improvements required for stream stabilization and will slow the pace of degradation such that funding resources can more easily keep up with the required improvements. At best, it may be found that watershed-wide full-spectrum detention may eliminate the need for capital improvements in some stream reaches.

The initial flow-control plan was focused on Castle Oaks, since in the near term this community contains the largest concentration of impervious area that will drain into the critical reaches of McMurdo Gulch. Eight existing Castle Oaks detention facilities, shown in Figure 4, were evaluated for potential retrofitting. Five of these facilities were designed with outlet structures that control the 10 year and 100 year flow rates, one facility was designed to capture and slowly release only the water quality capture volume (WQCV), and two facilities were designed to control the WQCV and the 10 year and 100 year events.

A simple way to retrofit a detention pond designed with a 10 year and 100 year release to a full-spectrum facility is to reduce the size of the 10 year outlet to provide a minimal release rate for the 10-year volume. This is because the UDFCD simplified equation for 10 year detention volume yields about the same number as the excess urban runoff volume (EURV) required for full-spectrum detention (full-spectrum detention is based on capturing the EURV and draining it slowly -- over a period of up to 72 hours -- to minimize the EURV release rate. This method of retrofitting was the primary approach that was evaluated for the Castle Oaks ponds.

Design plans for the eight Castle Oaks detention facilities and the supporting design report and CUHP and SWMM models were obtained and reviewed. Significant time was invested to understand the design intent and modeling of the existing detention facilities. In some cases, the stage storage and stage discharge relationships for the ponds were revised to achieve complete consistency with the design plans. Then, various retrofitting alternatives were evaluated.

Based on the results of the modeling, the recommended retrofit plan consists of providing smaller orifices to reduce the 10 year outlets of Ponds 335, 355, 360, and 390. The recommended plan meets the intent of reducing peak discharges to levels similar to or less than pre-developed conditions for a full spectrum of storms, including the frequent events that contribute to stream degradation. This is illustrated in Figure 5, which shows the combined contribution of flow from the three Castle Oaks sub-

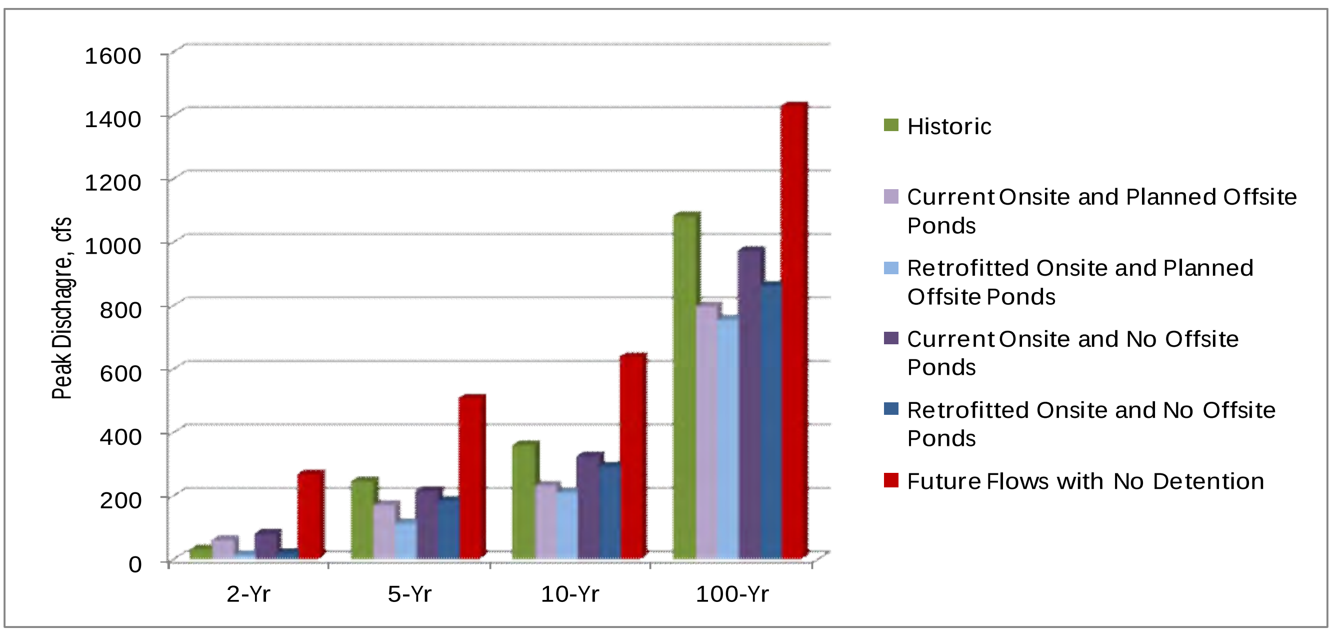

Figure 5. Comparison of combined outflows from Castle Oaks tributaries showing effectiveness of detention pond retrofit improvements.

watersheds to McMurdo Gulch. The light blue and dark blue bars (with and without offsite ponds) show that the combined outflows for the proposed retrofit plan are less than those for the current ponds and less than pre-developed conditions for all events, including the smaller, more frequent storms such as the 2-year. Although additional flow reductions would be possible by providing additional detention storage volume through raised spillways or excavation, based on the modeling completed these more extensive retrofit measures are not necessary to reduce discharges below pre-developed levels.

In addition to these recommended retrofit improvements, it is essential that future detention ponds implemented as part of new development be designed as full-spectrum detention facilities and modeled to ensure that runoff levels remain close to historic. Initial coordination between the Town of Castle Rock, Douglas County, and CCBWQA took place during the design process to define a common requirement of implementing full-spectrum detention for all future development within the basin.

Step 5. Develop Proactive Stream Reclamation Plan

A reclamation plan was developed to address the portions of McMurdo Gulch most susceptible to erosion. The improvements are located over a three mile reach adjacent to and downstream of the Castle Oaks tributaries where the existing watershed imperviousness exceeds 10 percent, as indicated in Figure 2. This is the portion of the gulch most at risk from stresses imposed by increased stormwater runoff and shows signs of weakness in a number of spots.

Boulder cascade drops being constructed at critical locations to protect the Gulch against major erosion while preserving existing riparian vegetation.

The reclamation improvements consist of a combination of boulder cascade drop structures, rock lining, bioengineered bank protection, and riparian vegetation. The actual improvements are approximately 4,000 feet in length if arranged end to end, although individual measures are strategically distributed in the most critical locations throughout the three mile design reach. Critical areas were identified primarily based on signs of existing erosion observed in the field; however, an evaluation of shear stresses imposed on the channel and the ability of existing vegetation to withstand those stresses was also undertaken. The specific improvement measures are described in the following paragraphs:

A total of nineteen boulder cascade drop structures are being constructed (Castle Rock staff like to refer to these as “Castle-cade drops”). The boulder cascade structures are a new type of drop comprised of arches of boulders alternating with shallow pools filled with void-filled riprap. The drops have been designed to mimic the look and hydraulic function of a natural boulder “step-pool” pattern observed in mountain streams. The natural look and lack of concrete or grout helped these drops gain approval during the environmental permitting process.

In six locations, the invert of the channel is being reinforced with void-filled riprap lining. This material, which is similar to natural bed material in rocky streams, will protect the channel invert and fit within the confines of the relatively steep banks and steep longitudinal slopes better than drop structures. The channel lining will be installed at longitudinal slopes in the 2 percent range.

At two sections along McMurdo Gulch, bank protection is being installed consisting of buried soil riprap, erosion control blanket, and willow plantings. This bank protection will provide additional reinforcement in areas that will be subject to higher erosive forces at the outside of sharp bends.

The combination of stream improvements will modify the existing stream appearance to some degree, especially during and immediately after construction. However, the improvements are designed to emulate stream features that are found in nature, albeit generally in more mountainous terrain. The improvements also lend themselves to the establishment of vegetation within the rock material, allowing the features to blend in to the surrounding environment more as time goes by. If the improvements are not made, the appearance of the stream will be altered in a negative way through erosion and loss of vegetation.

Protection of existing riparian vegetation and revegetation of areas disturbed by construction will be an important component of this project. The upstream planting scheme was tailored to wetter conditions and more cohesive soils. The downstream planting scheme was tailored to dryer conditions and sandier soils. The revegetation effort will involve transplanting onsite willow bunches, shrubs, wetland grasses, and Cottonwood poles. In addition, nursery stock shrubs and wetland grasses will be planted to compli-

The revegetation effort is aimed at re-establishing wetland, transitional, and upland grasses, herbaceous species, and woody vegetation to provide healthy habitat and resistance to erosion.

ment the transplant material. Seeding and mulching of wetland and upland grasses will round-out the planting effort. The revegetation plan is designed to provide healthy stands of vegetation that will help resist erosive forces, enhance water quality, provide wildlife habitat, and maintain the aesthetic beauty of the corridor. In addition, the planting plan has been adapted to meet recent, more stringent, requirements set by the U.S. Corps of Engineers to replace impacted woody vegetation (trees, shrubs, and willows) at higher ratios.

The cost of the initial phase of reclamation improvements as determined by the contractor's bid amount plus the related design and construction engineering costs, about $1.3 million, will increase the level of protection over the most vulnerable three mile reach of McMurdo Gulch. This works out to a unit cost of about $80 per lineal foot for the Phase 1 improvements over that length, or about $325 per foot for the 4000 lineal feet of actual improvements. Since the improvements do not extend continuously over the entire three mile length and are not designed to prevent all erosion that might occur during a 100-year event or over time during lesser events, additional phases of improvements are expected to be necessary in the future (although there is some potential for the stream to remain stable after the initial phase of improvements for quite some time, especially with full-spectrum detention implemented in the watershed). The first phase of improvements will reinforce weak points in the Gulch to reduce and forestall the progression of erosion over the three mile reach at a far lower cost than undertaking an ultimate, conventional 100-year design.

By comparison, a conventional approach such as the one shown in the 2006 McMurdo Gulch master plan, where the channel is re-graded and flattened to a slope of 0.5 percent in between large 100-year drop structures, is estimated at $400 to $500 per lineal foot in 2011 dollars and would require a greater level of disturbance to the existing Gulch.

Timing of implementation of stream stabilization improvements affects construction costs. If, like many stream channels, McMurdo Gulch was allowed to undergo significant degradation prior to obtaining funding and undertaking stream stabilization improvements, costs would likely be even higher than the master plan estimates. Based on actual projects constructed on similar size drainageways in an eroded condition, unit costs could be greater than $600 per lineal foot.

Therefore, even if one or perhaps two additional phases of construction similar in scope to Phase 1 are ultimately required, the capital investment may still be on the order of half that required for a conventional approach. The approach would also stretch out the needed capital resources over a period of years, making it easier to dedicate funding.

The proactive approach taken in McMurdo Gulch represented an acceptable level of service, or risk, to the project sponsors. The risk of damage to the gulch and increased sediment and phosphorus loading to downstream receiving waters is significantly lower with the improvements than without the improvements, but still greater than if a conventional 100-year level of improvement was implemented. The required capital investment at his time was only 20 percent or less of a full 100-year project and the reduction of risk associated with the proactive improvements — or its relative value — is viewed as significantly greater than 20 percent of a conventional 100-year project. In other words, the benefit/cost ratio is higher for the proactive Phase 1 project than a conventional 100-year system of improvements constructed either early on or after degradation has occurred.

Step 6. Conduct Stream and Watershed Inventories Annually

It is recommended that any development in the McMurdo Gulch watershed be tracked and that the developed area and imperviousness for each tributary subwatershed and the overall watershed be updated on an annual basis. Any detention facilities to be constructed should be modeled and the design adjusted as necessary to provide full-spectrum detention (to ensure that developed runoff rates throughout the watershed are maintained at or below historic levels, especially for smaller events such as the 2-year storm). In addition, it is recommended that opportunities for retrofitting full-spectrum detention into existing detention facilities be pursued.

It is recommended that stream inventories along McMurdo Gulch and major tributaries be conducted annually, assessing how the initial reinforcement improvements are functioning, how revegetation establishment is progressing, and whether any signs of additional instability are noticed in reaches not addressed in the initial improvements. A brief annual report should be prepared to document findings and present any recommendations for further improvements. When the need for additional improvements becomes evident, it will be necessary to follow-up through design, funding, and implementation.

Conclusion

A six-step reclamation approach has been implemented at the early stages of development in the McMurdo Gulch watershed. The elements of the approach consist of:

1. **Start the process early**
2. **Examine land use in the watershed**
3. **Inventory the stream**
4. **Develop plan to implement full-spectrum detention**
5. **Develop proactive stream reclamation plan**
6. **Conduct stream and watershed inventories annually**

The McMurdo Gulch template study has led to several key conclusions:

- The study offers confirmation of threshold values of watershed imperviousness that are associated with the onset of impacts to stream systems. Threshold values presented in the literature are about 10 percent watershed imperviousness. This study suggests that the impacts are starting to be felt at an average watershed imperviousness of approximately 8 percent (and a maximum weighted imperviousness of 13 percent downstream of one developing tributary area). It is recommended that a proactive approach to mitigate impacts begin when a watershed imperviousness reaches about 5 percent.

- The study gives Castle Rock a tool and road map to stay ahead of stream degradation and associated problems prior to conditions deteriorating, avoiding severe impacts and costly repairs.

- The design of improvements to help stabilize the drainageway, while slightly changing the appearance of the gulch, mimics natural stream features and establishes conditions favorable for moisture and vegetation to fill in and soften visual impacts over time.

- The project comprises a watershed-wide test case to demonstrate the effectiveness of full-spectrum detention in reducing stream degradation impacts. Continued monitoring over time should shed some light on the ability of consistently-implemented full-spectrum detention to reduce the degree to which streams need to be stabilized.

- The proactive reclamation approach used at McMurdo Gulch offers a relatively low cost, low disturbance method of staying ahead of degradation impacts along stream corridors and protecting water quality, habitat, and infrastructure.

The unique design process undertaken for the reclamation of McMurdo Gulch in the three mile study reach can serve as a guide, or “template” for the reclamation of similar tributary streams in the upper Cherry Creek watershed.