COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Colorado Water Conservation Board

Water Plan

Water Project Summary

Name of Applicant	Town of Buena Vista
Name of Water Project	Project-01905 Infiltration Gallery Expansion Project
Grant Request Amount	**$1,107,750.00**
Primary Category	$1,107,750.00
Water Storage & Supply	
Total Applicant Match	**$0.00**
Applicant Cash Match	
Applicant In-Kind Match	
Total Other Sources of Funding	**$0.00**
Total Project Cost	**$1,107,750.00**

Applicant & Grantee Information

Name of Grantee: Town of Buena Vista
Mailing Address: P.O. Box 2002 Buena Vista Colorado 81211
FEIN: 846,000,568

Organization Contact: Shawn Williams
Position/Title: Email: bvpwdir@buenavistaco.gov
Phone: 719 396 6898

Grant Management Contact: Shawn Williams
Position/Title: Email: bvpwdir@buenavistaco.gov
Phone: 719 396 6898

Description of Grantee/Applicant

No description provided

Type of Eligible Entity

- ☐ Public (Government)
- ☐ Public (District)
- ■ Public (Municipality)
- ☐ Ditch Company
- ☐ Private Incorporated
- ☐ Private Individual, Partnership, or Sole Proprietor
- ☐ Non-governmental Organization
- ☐ Covered Entity
- ☐ Other

Category of Water Project

- ☐ Agricultural Projects
  Developing communications materials that specifically work with and educate the agricultural community on headwater restoration, identifying the state of the science of this type of work to assist agricultural users among others.
- ☐ Conservation & Land Use Planning
  Activities and projects that implement long-term strategies for conservation, land use, and drought planning.
- ☐ Engagement & Innovation Activities
  Activities and projects that support water education, outreach, and innovation efforts. Please fill out the Supplemental Application on the website.
- ☐ Watershed Restoration & Recreation
  Projects that promote watershed health, environmental health, and recreation.
- ■ Water Storage & Supply
  Projects that facilitate the development of additional storage, artificial aquifer recharge, and dredging existing reservoirs to restore the reservoirs' full decreed capacity and Multi-beneficial projects and those projects identified in basin implementation plans to address the water supply and demand gap.

Location of Water Project

Latitude	38.834153
Longitude	-106.168621
Lat Long Flag	Water provider location: Coordinates based on address of water provider
Water Source	Groundwater Source. Cottonwood Creek Water Rights
Basins	Arkansas
Counties	Chaffee
Districts	11-Arkansas: Headwaters to Salida

Water Project Overview

Major Water Use Type	Municipal
Subcategory	Construction
Scheduled Start Date - Design	1/1/2022
Scheduled Start Date - Construction	10/1/2022

Description

The project will consist of expanding the Town’s primary drinking water source. the existing infiltration gallery (IG), to utilize the Town’s full portfolio of water rights. Currently the IG is capable of producing up to 800 gpm. To access the full water rights of the Town, the IG needs to be expanded to 1,740 gpm or 2.5MGD. This expansion meets the Town’s 20 year growth projections. The funding acquired from CWCB will be used for the design and construction of the expansion project. There are currently 1,810 active taps in Town. The expansion will help bring on a redundant water supply and the ability for the Town to add taps to the current system as further development continues.

Measurable Results

New Storage Created (acre-feet)
New Annual Water Supplies Developed or Conserved (acre-feet), Consumptive or Nonconsumptive
Existing Storage Preserved or Enhanced (acre-feet)
New Storage Created (acre-feet)

Length of Stream Restored or Protected (linear feet)
Efficiency Savings (dollars/year)
Efficiency Savings (acre-feet/year)
Area of Restored or Preserved Habitat (acres)
Quantity of Water Shared through Alternative Transfer Mechanisms or water sharing agreement (acre-feet)
Number of Coloradans Impacted by Incorporating Water-Saving Actions into Land Use Planning
Number of Coloradans Impacted by Engagement Activity

Water Project Justification

This project supports the goals of the Colorado Water Plan as it
- demonstrates sustainability in the community and a reduced impact on the environment, and will help avoid adverse effects to both environmental and watershed health by accessing water from the IG rather than accessing water rights from Cottonwood Creek
- serves to mitigate economic and social impacts on agricultural and rural communities within the basin,
- the project's fiscal and technical feasibility demonstrates an intent to leverage local or state funding, and
- upon receipt of funds, the project will be ready for construction

The Arkansas River Basin Implementation Plan has specific goals for consumptive/municipal use. Although the BIP does not specifically call out a goal for municipal transfers and permanent dry-up of basin cropland, it is discussed. By accessing water from the IG, more water will remain in Cottonwood Creek for irrigation purposes, supporting the idea of avoiding permanent dry-up. The BIP has four specific goals for municipal water needs.
1. Meet the municipal supply gap in each county within the basin;
2. Support regional infrastructure development for cost-effective solutions to local water supply gaps;
3. Reduce or eliminate Denver Basin groundwater dependence for municipal users; and,
4. Develop collaborative solutions between municipal and agricultural users of water, particularly in drought conditions.

This project serves to support goals 1, 2, and 4, by:
1. increasing capacity of the Town's water system, a supply gap is reduced,
2. installing infrastructure to expand the IG uses existing technology and minimizes costs to the tax base by accessing the superior quality water from the IG rather than treating surface water, which yields many challenges and risks associated with environmental factors. (Support from the 2021 JVA Demonstration Project)
4. continuing to access water from the IG leaves more water in Cottonwood Creek for irrigation and agricultural use, particularly under drought conditions.

The Town will not be acquiring new water rights, the Town has existing rights that are not used. The new infrastructure will be used to utilize the existing water rights to expand the capacity of the system.

Related Studies

Three reports were completed in summer 2021.

1. A demonstration project was conducted to understand the feasibility of treating surface water from Cottonwood Creek and bringing the existing surface water treatment plant back online. The PDR concluded that brining the surface water treatment plant back online was a more expensive option than expanding and treating IG water.
2. The Town contracted with Wright Water Engineers to complete a Water Resources Master Plan, which was adopted by the Town in October 2021.
3. Hemenway Engineering completed a feasibility evaluation for expanding the IG, It was concluded that horizontal wells could be constructed to access additional IG water to maximize the Town's existing water rights.

All three documents are included as supplemental documents.

Taxpayer Bill of Rights

No Tabor issues exist. . It is the Town's goal to apply and execute all grants in 2022 to maintain TABOR Enterprise status of the Water Enterprise Fund in the year of receipt.

Budget and Schedule

This Statement of Work shall be accompanied by a combined Budget and Schedule that reflects the Tasks identified in the Statement of Work and shall be submitted to CWCB in excel format.

Reporting Requirements

Progress Reports: The applicant shall provide the CWCB a progress report every 6 months, beginning from the date of issuance of a purchase order, or the execution of a contract. The progress report shall describe the status of the tasks identified in the statement of work, including a description of any major issues that have occurred and any corrective action taken to address these issues.

Final Report: At completion of the project, the applicant shall provide the CWCB a Final Report on the applicant's letterhead that: (1) Summarizes the project and how the project was completed. (2) Describes any obstacles encountered, and how these obstacles were overcome. (3) Confirms that all matching commitments have been fulfilled. (4) Includes photographs, summaries of meetings and engineering reports/designs. The CWCB will pay out the last 10% of the budget when the Final Report is completed to the satisfaction of CWCB staff. Once the Final Report has been accepted, and final payment has been issued, the purchase order or grant will be closed without any further payment.

Payment

Payment will be made based on actual expenditures and must include invoices for all work completed. The request for payment must include a description of the work accomplished by task, an estimate of the percent completion for individual tasks and the entire Project in relation to the percentage of budget spent, identification of any major issues, and proposed or implemented corrective actions. Costs incurred prior to the effective date of this contract are not reimbursable. The last 10% of the entire grant will be paid out when the final deliverable has been received. All products, data and information developed as a result of this contract must be provided to as part of the project documentation.

Performance Measures

Performance measures for this contract shall include the following: (a) Performance standards and evaluation: Grantee will produce detailed deliverables for each task as specified. Grantee shall maintain receipts for all project expenses and documentation of the minimum in-kind contributions (if applicable) per the budget in the Budget & Schedule Exhibit B. Per Water Plan Grant Guidelines, the CWCB will pay out the last 10% of the budget when the Final Report is completed to the satisfaction of CWCB staff. Once the Final Report has been accepted, and final payment has been issued, the purchase order or grant will be closed without any further payment. (b) Accountability: Per Water Plan Grant Guidelines full documentation of project progress must be submitted with each invoice for reimbursement. Grantee must confirm that all grant conditions have been complied with on each invoice. In addition, per Water Plan Grant Guidelines, Progress Reports must be submitted at least once every 6 months. A Final Report must be submitted and approved before final project payment. (c) Monitoring Requirements: Grantee is responsible for ongoing monitoring of project progress per

Exhibit A. Progress shall be detailed in each invoice and in each Progress Report, as detailed above. Additional inspections or field consultations will be arranged as may be necessary. (d) Noncompliance Resolution: Payment will be withheld if grantee is not current on all grant conditions. Flagrant disregard for grant conditions will result in a stop work order and cancellation of the Grant Agreement.

Infiltration Gallery Expansion Project Scope

PROJECT LOCATION

The Town's Water Treatment Plant is located on Chaffee County Road 306, 2.2 miles west of Colorado State Highway 24.

EXISTING RAW WATER SOURCES

The Town's oldest and preferred water right allows the Town to utilize groundwater and surface water surface water from Cottonwood Creek, for municipal use.

GROUNDWATER SOURCES

The Infiltration Gallery (IG) is the Town's primary source of water. From fall through spring, the IG can supply 400 gpm to the WTP. During summer months when water demands peak, Town staff is capable of increasing supply from the IG to 800 gpm.

* From a water quality perspective, the Infiltration Gallery (IG) is the preferable water source. Pretreatment for IG water is not needed due to the historically high-water quality throughout the year. The IG source water has been serving the Town since 1974 and has never exceeded CDPHE secondary and primary drinking water standards. The IG infrastructure in does need to be expanded and the Towns water rights can provide this effort without the need to seek addition water rights. The I.G. also provides les risk to the towns water supply from potential environmental impacts such as fire and flooding. Also typically ground water source are less vulnerable to contaminants and harmful pathogens.

Project Scope

The Town of Buena Vista along with the engineering consultants produced a Preliminary Design Report. Pilot studies were performed as well. The IG expansion project is the desired source moving forward. Design and CDPHE review is still needed but the scope of the project will include:

- **Installing new redundant lateral collection piping to collect the ground water sources similar to the Towns existing system.**
- **Install a new creek crossing to supply the water treatment plant.**

Deep Trenching Technology

Addition files have been provided with this grant application and provide a more detail description of the IG expansion method. Also Provided is the JVA Preliminary Design Report. According to the Hemenway Groundwater Report, two new IG laterals installed in Gorrel Meadows (town owned property) east of the existing IG will increase IG production to 2.5 MGD. The new laterals will be located so their construction minimizes disruption to the existing IG. The laterals will be installed at a depth of 20 feet and consist of perforated high density polyethylene (HDPE) pipe. The horizontal pipe will convey the water to a large diameter vertical pipe wetwell equipped with a submersible or vertical turbine pump that will pump the water to the new WTP building. Refer to the HGE report for details.

A new transmission pipe will be installed below Cottonwood Creek to convey the water from the new IG laterals. The new IG will function as a completely separate system from the existing IG, allowing for some redundancy if either IG fails or is taken offline for maintenance.

Treatment

Water from the existing and expanded IG will be networked and conveyed to a raw water pump station located at the WTP site. The raw water pump station will pump the IG water to an array of cartridge filters located in a new building. The filtration booster pumps will contain variable frequency drives (VFDs) that ramp the pumps up and down to maintain a designated flowrate through the filters as headloss develops in the filter cartridges. The flowrate of these pumps will be set by the operators to accommodate system water demands. After filtration, chlorine is added to the filtered water and directed to clearwell for disinfection contact time. Chlorine addition to the filtered IG water is required to achieve disinfection.

*The Town of Buena Vista (Town) owns and operates a community water system (PWSID No. CO 0108300) that provides drinking water to residential, municipal, and commercial customers located within the Town's service area. The population within the Town's service area is approximately 2,906 full time residents. The Town is considering improvements to the water treatment plant (WTP) to meet surface water treatment regulations and to increase capacity for meeting current and future water demands as the population continues to grow within the service area. The Town owns senior surface water rights for Cottonwood Creek that are currently not being fully exercised due to limitations of their existing water treatment process capabilities. In this preliminary design report, alternatives for treatment and increasing the capacity of the WTP are evaluated. The Town also owns an existing surface water treatment plant with a treatment capacity of 1.0 million gallons per day (MGD), which has been decommissioned since 1999.

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Water Plan Grant - Detailed Budget Estimate
Fair and Reasonable Estimate

Prepared Date: 1-Dec-21
Name of Applicant: Town of Buena Vista
Name of Water Project: Infiltration Gallery Expansion Project

EXAMPLE C: Construction

Task 1 - Construction						
Sub-task	Unit	Quantity	Unit Cost	Total Cost	**CWCB Funds**	**Matching Funds**
Mobilization		1	$ 141,400	$ 141,400	$ 70,700	$ 70,700
Horizontal Wells for IG Expansion	LS	1	$1,157,100	$ 1,157,100	$ 578,550	$ 578,550
Task 2 - IG Pump Installation						
IG Transfer Pump		2	$ 56,000	$ 112,000	$ 56,000	$ 56,000
Site Piping	LS	1	$ 140,000	$ 140,000	$ 70,000	$ 70,000
Electrical and Backup Power Supply	LS	1	$ 250,000	$ 250,000	$ 125,000	$ 125,000
Instrumentation and Controls	LS	1	$ 140,000	$ 140,000	$ 70,000	$ 70,000
Task 3 - Design, Permitting and Construction Administration						
Engineering, Permitting, & Design	LS	1	$ 183,000	$ 183,000	$ 91,500	$ 91,500
Bidding & Construction Administratioı	LS	1	$ 92,000	$ 92,000	$ 46,000	$ 46,000
TOTAL					$ 1,107,750	$ 1,107,750

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Water Plan Grant - Proposed Schedule

Prepared Date: 12/1/2021 **1-Dec-21**
Name of Applicant: Town of Buena Vista
Name of Water Project: Infiltration Gallery Expansion Project

Project Schedule

Infiltration Gallery Design and Construction Schedule	
Anticipated Project Schedule	*Completion Date*
Groundwater Study	Complete
Prelimiary Design Report and Pilot Study Complete	Complete
Engineering and Design 30%	February 1, 2022
Enviormental Assesment	February 1, 2022
CMAR (if approved) and Bid Selection	March 1, 2022
Notice to Proceed for Construction	September 1, 2022
Substansial Completion of Infiltration Gallery Expansion Project	October 1, 2023
Water Treatment Plant Design and Construction (Phases unaccociated with this grant request)	
SRF Funding and Project Needs Assesment	January 15 2022
SRF Design and Engineering Grant	January 15 2022
CDPHE Design Approval	August 15, 2022
Notice to Proceed for Construction	September 1, 2022
Substansial Completion of Both Phases	October 2023/2024

*The construction schedule is dependent on which water treatment alternative the Town selects.

Gorrell Meadows Horizontal Well Cost Estimate

TO: Richard Hood/JVA Consulting Engineers

COPIES:

FROM: Courtney Hemenway

DATE: September 14, 2021

RESPOND BY:

Hemenway Groundwater Engineering (HGE) was contracted by the JVA Consulting Engineers (JVA) to provide an analysis of the viability and potential costs to install horizontal well(s) in the Gorrell Meadows alluvial aquifer system that currently provides water supply to the Town of Buena Vista (Town), Colorado. The town currently operates an infiltration gallery in the Gorrell Meadows alluvial aquifer with the location shown in Figure 1 (from Providence Infrastructure Consultants). The existing infiltration gallery or horizontal wells currently do not produce sufficient flow to meet future water supply demands for the Town. In 2019, HGE and Town staff investigated the alluvial materials beneath the meadows area by conducting several shallow (10- to 15-feet deep) “pot holes” with a town backhoe. In addition, eight monitoring wells were installed in December 2019 and equipped with water level transducers and data loggers to evaluate the alluvial groundwater system beneath the Gorrell Meadows. The data loggers began the collection of water level data in each of the monitoring wells in January 2020. Water level data has been collected continuously in the wells since that date.

A virtual meeting was conducted with staff from the Town, JVA, Wright Water Engineers, and HGE. The results from the meeting indicated that there are constraints imposed by water rights limitations that restrict the installation of vertical wells in the Gorrell Meadows area. This was further confirmed in conversations with Shawn Williams from the Town. In addition, the installation of horizontal wells is limited to two quarter sections as shown in Figure 1(note: the location of the horizontal wells in this figure were preliminary locations that have been revised).

HGE contacted Becky Dewind of Dewind One-Pass Trenching (Dewind) to discuss the potential viability of installing horizontal wells using Dewind’s One-Pass installation procedure. Information from the pot holing investigation and monitoring well installations were provided to Dewind. Dewind indicated that the geology with large cobbles up to two feet in diameter that were exposed during the pot holing would be challenging, but the installation of the wells could be completed. Becky noted that they would use a larger machine than normally required to install a 20-foot-deep horizontal well in order to accommodate the large cobbles that would be encountered at the site. Dewind just recently completed a horizontal well in Steamboat Springs in similar geologic conditions that was highly productive.

The depth of 20 feet from the horizontal piping was selected since deeper installations would become increasingly difficult to install based on the geology. At a depth of 20 feet, the new horizontal wells would be 10 feet deeper than the majority of the existing infiltration gallery. The additional depth would increase the available driving head to the well and increase the rate and duration of flow available from the well.

The proposed construction of the horizontal wells would be completed with up to 500 feet of horizontally placed 6-inch diameter HDPE slotted pipe. The well would be completed on one end with a 16-inch-diameter vertical sump, and at the opposite end the 6-inch-diameter HDPE would come to ground surface and be used as a clean-out for the system. The 16-inch sump would be used to install a submersible pump to produce water from the horizontal section of the well. Dewind's installation procedure installs the vertical sump and the horizontal piping with bedding gravel in a one-pass continuous process. The horizontal piping would be placed with clean, washed 3/8-inch pea gravel from the base of the trench (20 feet) to approximately 5 feet below grade. The area from 5 feet to ground surface would be filled with native fill from the excavation.

The construction of the horizontal well with a vertical sump for production from the well would provide control of flow from the Gorrell Meadows alluvial aquifer system. The evaluation of the monitoring well data from the eight monitoring wells installed in the Gorrell Meadows area indicated that the infiltration gallery significantly controls the alluvial groundwater system beneath the Gorrell Meadows. The continuous flow from the infiltration regulates and reduces the storage of water provided by the flood irrigation that the Town conducts to recharge the alluvial aquifer system with existing surface water rights. Using submersible pumps to produce water from the aquifer, rather than gravity flow, would provide the positive regulation of flow and storage within the aquifer.

Currently, the infiltration flows continuously throughout the year, regardless of water system demands. As water system demands increase, flow is collected from the infiltration gallery for disinfection and distribution to the potable water system for Buena Vista. By not controlling the flow from the infiltration gallery during periods of lower demand, there is a significant volume of groundwater that is not being captured and stored in the aquifer for later use in high-demand periods.

By adding controls to the flow from the infiltration gallery, there is the potential to significantly increase the storage of water within the alluvial aquifer system at the Gorrell Meadows. By increasing the storage volume in the aquifer, higher flow rates and greater volumes would be available from the aquifer during high-demand periods. By controlling the outflow from the aquifer, the estimated increased volume of available storage would be 108 acre-feet (see HGE Technical Memorandum *Gorrell Meadows Alluvial Monitoring Well Report January 2020 to May 6, 2021* dated June 3, 2021).

HGE evaluated the installation of two to three horizontal wells in the Gorrell Meadows area. The three locations are shown in Figure 2. Two locations are situated in the irrigated portion of the Gorrell Meadows on the north side of Cottonwood Creek. The third location is shown on the south side of Cottonwood Creek on Town property adjacent to the existing water storage tank. One proposed location on the north side of Cottonwood Creek would be placed downgradient of the existing infiltration gallery. As noted, the depth of the new horizontal well would be 20 feet deep, or 10 feet deeper that the existing infiltration gallery depth. The proposed well would extend across the entire alluvial aquifer system, perpendicular to Cottonwood Creek. That orientation would maximize the interception of downgradient water flow through the alluvial aquifer. Evaluation of the monitoring well data (see Technical Memorandum dated June 3, 2021) indicated that there is minimal influence from Cottonwood Creek in the immediate area of the Gorrell Meadows and that water in the aquifer at that location is from downgradient flow through the aquifer and imposed recharge from the irrigation of the meadows. The second location shown on the north side of Cottonwood Creek (Figure 2) would be installed if the production from the first well is limited and the location on the south side of Cottonwood Creek is not feasible. The location of the well would be parallel to Cottonwood Creek to intercept any additional flow not collected from the first well that is perpendicular to the river.

The third proposed well location is situated on the south side of Cottonwood Creek. The review of limited geologic and lithologic data indicates similar alluvial materials as identified on the north side of Cottonwood Creek. Location of this well would provide additional interception of the downgradient flow through the alluvial aquifer system and not interfere with the operation of the wells on the north side of the river and thereby provide additional capacity to the Town's water supply. If the wells produce 1,000 gallons per minute (gpm) to more than 1,500 gpm, the location of the southern well would allow for significant redundancy to the water supply system. Future water supply demands have been estimated at 2,000 gpm.

Cost Estimate

HGE provided geologic and lithologic data to Becky Dewind to enable her to provide a cost estimate to install up to three horizontal wells for the Town. Becky provided a cost estimate with general conditions for the installation of the wells. The cost estimate and general conditions are attached. If two wells are installed the cost per well would be $350,000. If three wells are installed, the per well cost would be $315,000.

The cost estimate provides for the main components for installing the wells. However, additional costs would be incurred for the gravel bedding of the wells and for equipment required to be provided to Dewind during the well installations. Costs for the gravel were provided from ACA Products of Buena Vista. Each well would require approximately 550 cubic yards of bedding gravel. Costs for 550 cubic yards of washed 3/8-inch pea gravel would be $35,000.

Dewind requires that the Town provide an excavator with a reach up to 20 feet and two 4 to 5 yard front end loaders. The loaders are required to move and place the gravel bedding into the feed hopper during the installation of the wells. Joe Pedre contacted Four Rivers equipment to obtain cost estimates for a week's rental of the equipment. Costs for rental of the equipment for one week would be $6,500.

Engineering fees for HGE during the permitting, field observation of the well installations, testing of the wells, and providing a well completion report for the wells would be $25,000 to $30,000. Testing of the wells would include a 3.5-hour variable-rate pumping test and a 72-hour continuous-rate pumping test. At the conclusion of the 72-hour test, a full-range water quality sample would be collected. Costs for the water sample would be approximately $4,000 and **are not** included in the estimate.

A summary of the costs is shown in the following table.

Summary of Costs for Town of Buena Vista Horizontal Wells			
Item	**Cost per Well**	**Cost for 2 Wells**	**Cost for 3 Wells**
Well Installation	$315,000 (3) or $350,000 (2)	$700,000	$945,000
Gravel Bedding	$35,000	$70,000	$105,000
Rental Equipment		$6,500	$13,000
Well Testing	$25,000	$50,000	$75,000
Permitting and Engineering		$25,000	$30,000
Total Costs		**$851,500**	**$1,168,000**

Costs for final equipping of the wells, well head facilities, transmission piping, electrical service fees, and other associated costs to incorporate the wells into the Town's water supply and treatment facilities are not included.

Preliminary Design Report

Town of Buena Vista
Water Treatment Plant

September 30, 2021

CONSULTING ENGINEERS

PRELIMINARY DESIGN REPORT

FOR THE

TOWN OF BUENA VISTA
WATER TREATMENT PLANT

JVA, Inc.
1512 Larimer Street
Denver, CO 80202
phone: 303-444-1951

JVA Project No. 1133e

SEPTEMBER 30, 2021

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EXECUTIVE SUMMARY

The Town of Buena Vista (Town) relies on the Infiltration Gallery (IG) located in Gorrel Meadows to supply raw water year-round for the Town's potable water demand. The existing IG and supporting infrastructure has a maximum production rate of 1.15 million gallons per day (MGD). Summer peak day demand currently exceeds 1.15 MGD, and the Town supplements the IG with water from Well 2. This report evaluates alternatives to construct a new water treatment plant (WTP) that can treat up to 2.5 MGD of potable water utilizing the Town's full water rights from Cottonwood Creek.

SOURCE WATER

The Town's water rights allow the Town to source a maximum of 2.5 MGD from either the Gorrel Meadows or Cottonwood Creek. An existing WTP designed to treat surface water directly from Cottonwood Creek was abandoned in 1999. The IG water is superior quality and requires less treatment than the Cottonwood Creek surface water. Currently the IG is classified as groundwater but will likely be reclassified as groundwater under the direct influence (GWUDI) of surface water which will require compliance filtration. The Cottonwood Creek surface water contains constituents of concern including iron and total organic carbon (TOC) that will require treatment processes designed to target their removal to comply with Colorado's Primary Drinking Water Regulations.

PROJECT ALTERNATIVES

This report analyzed alternatives to treat either the IG water or Cottonwood Creek surface water. Since the IG is better water quality, any treatment process that is sufficient for Cottonwood Creek surface water will also be sufficient for IG water. The Town's goals are to:

- Supply high quality water to the Town's customers
- Have reliable and redundant water supply and treatment system
- Maintain a Class B operator requirement, if possible
- Limit operations, maintenance, and capital cost

The project alternative to treat IG water includes installing a new redundant IG with a 2.5 MGD capacity, compliance cartridge filtration, pH adjustment, and onsite sodium hypochlorite generation. The project alternative to treat Cottonwood Creek surface water includes reconstructing the Cottonwood Creek intake structure, rehabbing the presedimentation pond, installing pretreatment, gravity membrane filters, and onsite sodium hypochlorite generation.

The draft Town of Buena Vista Water Resources Master Plan (WRMP), prepared by Wright Water Engineers, Incorporated, dated August 23, 2021, recommends the Town have the ability to treat both IG water and Cottonwood Creek surface water. The project alternative to treat both IG and Cottonwood Creek surface water includes installing a new redundant IG with a 2.5 MGD capacity, reconstructing the Cottonwood Creek intake structure, rehabbing the presedimentation pond, installing pretreatment, gravity membrane filters, pH adjustment, and onsite sodium hypochlorite generation. Table 1 summarizes the non-monetary considerations for the two projects.

Table 1 – Non-Monetary Considerations of Project Alternatives

Project Alternative	Advantages	Disadvantages
IG using Cartridge Filtration	• Superior water quality • Simpler treatment • Lower ORC license required • No liquid waste stream	• Cannot utilize Cottonwood Creek surface water • Throw away cartridges
IG and Cottonwood Creek Surface Water using Gravity Membranes	• Redundant sources • More resilient treatment process	• Requires pretreatment • Liquid waste stream • Higher ORC license required

*ORC is the operator in responsible charge

Table 2 presents the capital, annual operations and maintenance (O&M), and 20-year net present value costs for each project alternative. The alternative to treat to only the IG water using cartridge filtration has a lower capital and O&M cost. The alternative to treat the IG and Cottonwood Creek surface water using gravity membranes requires improvements to both the IG and existing intake structure and requires equipment that is more expensive to purchase and operate.

Table 2 – Project Costs Comparison

Parameter	IG Using Cartridge Filtration	IG and Cottonwood Creek Surface Water using Gravity Membranes
Capital Cost	$5,127,500	$11,317,000
Annual O&M Cost	$ 79,033	$ 110,625
Total 20-year Net Present Value (Capital + O&M)	$6,678,800	$13,664,300

PROJECT RECOMMENDATION

The WRMP recommends the Town have the ability to treat IG and surface water to maximize the resiliency of the Town's water supply system. While this alternative is more costly than treating only the IG using cartridge filtration, it is much more resilient and provides the Town with the most redundancy for meeting future water demand.

SECTION 1 – BASIC PROJECT INFORMATION

The Town of Buena Vista (Town) owns and operates a community water system (PWSID No. CO 0108300) that provides drinking water to residential, municipal, and commercial customers located within the Town's service area. The population within the Town's service area is approximately 2,906 full time residents. The Town is considering improvements to the water treatment plant (WTP) to meet surface water treatment regulations and to increase capacity for meeting current and future water demands as the population continues to grow within the service area. The Town owns senior surface water rights for Cottonwood Creek that are currently not being fully exercised due to limitations of their existing water treatment process capabilities. In this preliminary design report, alternatives for treatment and increasing the capacity of the WTP are evaluated. The Town also owns an existing surface water treatment plant with a treatment capacity of 1.0 million gallons per day (MGD), which has been decommissioned since 1999.

The Town's WTP receives water from an infiltration gallery (IG) located within the North Cottonwood Creek alluvium, known as Gorrel Meadows, located to the west of the WTP. Raw water collected by the IG is currently considered to be groundwater by the Colorado Department of Public Health and Environment (CDPHE) and therefore only requires disinfection prior to distribution. However, it is likely the IG source will be reclassified as groundwater under direct influence (GWUDI) of surface water in the future. The IG is currently the primary source of water for the Town. The Town has three additional ground water wells. The Town relies on Well 2 to supplement IG water during high demand. Together, these two sources have a maximum production of approximately 1.15 MGD.

PROJECT LOCATION

The Town's WTP is located on Chaffee County Road 306, 2.2 miles west of Colorado State Highway 24. A map of the service area and project location is shown in Figure 1.

EXISTING RAW WATER SOURCES

The Town's oldest and preferred water right allows the Town to utilize groundwater from Gorrel Meadows, surface water from Cottonwood Creek, and surface water from North Cottonwood Creek for municipal use. The Town has additional groundwater rights which allow them to operate groundwater wells in Town limits.

GROUNDWATER SOURCES

The IG at Gorrel Meadows is the Town's primary source of water. From fall through spring, the IG can supply 400 gpm to the WTP. During summer months when water demands peak, Town staff can apply surface water from North Cottonwood Creek to the Gorrel Meadows, increasing supply from the IG to 800 gpm.

FIGURE 1 - WATER SERVICE AREA BOUNDARY

TOWN OF BUENA VISTA PDR

SEPTEMBER 2021

CONSULTING ENGINEERS

JVA, Inc.
1319 Spruce Street
Boulder, CO 80302
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Well 1, which is located at the Rodeo Grounds, has a production rate of 15 gallons per minute (gpm). Water from Well 1 only provides water to the rodeo grounds and is not connected to the distribution system. Well 2 is a 100-foot deep alluvial well located at the WTP site and is used to supplement flows from the IG. When in production, groundwater from Well 2 is combined with water from the IG in a vault located on the northeast side of the WTP and disinfected with chlorine prior to entering the distribution system. Well 3 is located at the River Park on the east side of Town and is disinfected at the well site prior to entering the distribution system. A summary of the existing groundwater wells is provided in Table 3.

Table 3 – Town of Buena Vista Raw Water

Well Name	Permit No.	Production Rate (gpm)	Depth (ft)	Use
IG	51396-F	1178	10	Domestic
Well 1 (Rodeo Grounds)	77257-F	15	57	Domestic, Municipal
Well 2 (At WTP)	78212-F	150	100	Domestic, Municipal
Well 3 (At River Park)	78531-F	100	88	Domestic, Municipal

Surface Water Sources

The Town's senior water rights on Cottonwood Creek allow water to be diverted at the Town's intake structure, referred to as the grizzly. Under current operations, the Town can reliably divert up to 3.88 CFS, or 2.5 MGD during the irrigation season, which is April through October.

Existing Water Treatment Plant

The WTP site consists of the Gorrel Meadow IG, a groundwater well (Well No.2), an intake structure on Cottonwood Creek, two pre-sedimentation ponds in series, a WTP building, and a chlorination building. The IG, which was installed in 1980, consists of perforated pipe buried between 8 and 16-feet below the ground surface and is designed to capture groundwater. Groundwater collected from the IG flows by gravity to the WTP. Delivered water from the IG combines with Well No. 2 (when in production) and is disinfected with chlorine gas in a junction vault located just east of the WTP building prior to entering the distribution system. Town Staff target a chlorine residual of 0.9 milligrams per liter (mg/L) at the point of entry.

Figure 2 – Existing Intake Structure

The surface WTP has been abandoned since 1999. A surface water intake structure is located on the west side the WTP property that can be used to divert water from the main stem of Cottonwood Creek into two pre-sedimentation ponds in series. The existing diversion structure is a sloping concrete drop structure approximately 5 feet high and 12 feet wide. The intake structure gate feeds an 18-inch pipe and flows by gravity to the pre-sedimentation ponds. The elevation of the weir at the point of diversion is a key variable for controlling the flow rate to the WTP and influences the floodplain. Peak stream flow ranges from 100 to 800 cubic feet per second (cfs) and the design of the diversion will be constrained by the impact on the floodplain.

Raw water flows by gravity from the lined 1-million-gallon (MG) pre-sedimentation ponds to the WTP building through a 18-inch ductile iron pipe. The WTP building, which was built in 1974, houses the treatment system which includes chemical pretreatment with a rapid mix system, flocculation, mixed media filtration, a backwash pumping and handling system, and a clearwell. The chemical pretreatment system consists of a polyaluminum chloride (PACl) storage tank and chemical feed pumps, a 6,000-gallon Alum storage tank, and a polymer chemical feed system. The chemicals are injected after the raw water enters the building, the water passes through a rapid mix, and then the flow of water is split between the two flocculation basins. Each basin is equipped with three over/under wooden baffles. The capacity of each flocculation basin is estimated to be 0.52 MGD (based on minimum flocculation time of 30 minutes), for a combined 1.03 MGD capacity.

Water from each flocculation basin then flows into a multi-media gravity filter. Each filter has 144 square feet of surface area. The filter media consists of 18-inches of anthracite, 12-inches of silica sand, a layer of garnet, and 15-inches of gravel. The filters are not equipped with a filter-to-waste option and therefor, do not meet current CDPHE design criteria. The capacity of the filters is estimated to be 1.04 MGD per train, or 2.07 MGD combined capacity. Filtered water is piped to a single, unbaffled, 33,000 gallon clearwell. Finished water can flow from the clearwell into the distribution system via a gravity pipeline, which is currently plugged to isolate the abandoned WTP from distribution.

The clearwell is equipped with a single vertical turbine pump used for filter backwash. The backwash flow rate is 2,500 gpm and is controlled through a modulating valve. Backwash waste is piped to one of two lined ponds located on the north side of the WTP. Decant from the backwash pond can be pumped back into the pre-sedimentation pond via submersible pumps. A figure of the existing WTP site is provided in Figure 3.

Distribution and Storage

The Town's distribution system consists of cast iron and ductile iron pipe with diameters of 4- to 18-inches, three potable water storage tanks, and two booster pump stations. The distribution system has two main gravity zones. A 1.5 MG tank serves the Lower Zone via gravity. Water from the Lower Zone is pumped to two 0.75 MG storage tanks in the Upper Zone via the Westmoor Booster Pump Station. There is also an offline pump station and 0.27 MG storage tank in the Ivy League area which is fed by gravity from the Upper Zone.

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FIGURE 3 - EXIST WTP

TOWN OF BUENA VISTA PDR

SEPTEMBER 2021

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Population and Demand Projections

According to the draft Town of Buena Vista Water Resources Master Plan (WRMP), prepared by Wright Water Engineers, Incorporated, dated August 23, 2021, the Town currently serves approximately 1,810 single family equivalents (SFEs). A single SFE represents the water use characteristics of a home of a single permanent resident in the Town. The WRMP determined that the average winter water demand is 210 gal/SFE/day, the average summer demand is 571 gal/SFE/day, and the peak day demand is 756 gal/SFE/day, which, when compared to the average annual water demand, results in a peaking factor of 2.2.

Based on the 2014 Master Plan, by RG & Associates (RGD), the Town's existing service area can accommodate 2,366 SFEs at buildout within the existing service area. The WRMP considered growth rates of 50 SFEs per year and 70 SFEs per year. At these growth rates average summer demand will exceed the existing IG capacity in 2023. The Town will reach buildout in 2028 or 2031, resulting in a peak day demand of 1.79 MGD. The WRMP assumes the Town will continue to grow at the same rate following buildout by expanding the water service area. Figure 4 illustrates the anticipated water production demand at a growth rates of both 50 and 70 SFEs per year. At these growth rates, the peak day demand will reach 2.5 MGD by 2041 or 2050. Figure 4 shows the future water demand.

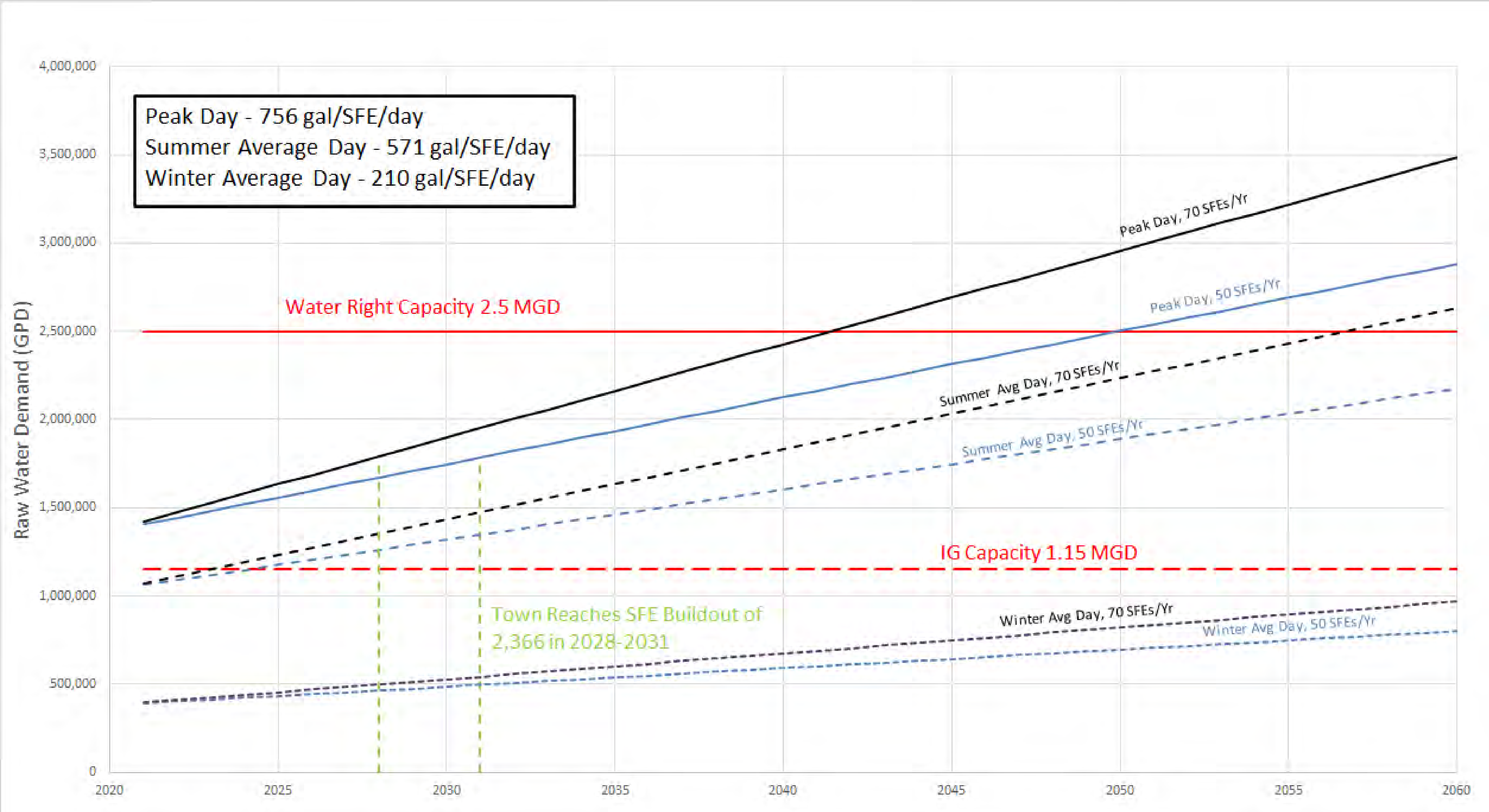

Figure 4 – Future Water Demand

SECTION 2 – SOURCE WATER QUALITY

Historical and recent water quality samples collected from the IG and Cottonwood Creek surface water are analyzed in this section. Understanding the water quality from each source is key to determining the processes necessary to treat the water to comply with Colorado's Primary Drinking Water Regulations (Regulations). The Regulations establish enforceable maximum contaminant levels (MCLs) for various constituents in the finished water provided to customers. The Regulations also include secondary maximum contaminant levels (SMCLs) for some constituents, which are recommended levels. Water quality lab results can be found in Appendix A.

INFILTRATION GALLERY WATER

The IG produces high quality water that historically has not required treatment beyond disinfection because it is classified as groundwater. It is anticipated that the Infiltration Gallery will likely be recategorized as GWUDI in the near future and that additional treatment will be required to comply with the surface water regulations. Water quality data from June 4, 2021, through August 7, 2021, are shown in Table 4. The Town monitors water quality data from online turbidimeters and regular grab samples. The Town regularly tests for several water quality characteristics including inorganic chemicals (IOCs), fluoride, nitrate, radionuclides, chlorine residual, coliform counts, disinfection byproducts (DBPs) consisting of total trihalomethanes (TTHMs) and haloacetic acids (HAA5s), and lead and copper in accordance with the Regulations and their monitoring schedule.

Table 4 – Summary of Raw Infiltration Gallery Water Quality

Constituent	Mean Value	Range of Values	Unit	Treated Water MCL
Turbidity	0.065	0.062 – 0.392	NTU	Varies
TOC	1.0	0.90 – 1.2	mg/L	-
DOC	1.0	0.8 – 1.1	mg/L	-
Diatoms[1]	0	-	Organism/100L	-
Other Algae[1]	13	-	Organism/100L	-
TSS	<5.0	BDL – 5.0	mg/L	-
Fluoride	0.14	-	mg/L	4 mg/L
Total Alkalinity	49.4	46.2 – 57.0	mg/L as $CaCO_3$	-
Bicarbonate	49.4	46.2 – 57.0	mg/L as $CaCO_3$	-
Carbonate	<4.0	BDL	mg/L as $CaCO_3$	-
Total Iron	0.01	BDL	mg/L	0.3 mg/L (SMCL)
Total Manganese	0.001	BDL – 0.001	mg/L	0.05 mg/L (SMCL)
Sodium	3.0	-	mg/L	-
Antimony	<0.001	-	mg/L	0.006 mg/L

Constituent	Mean Value	Range of Values	Unit	Treated Water MCL
Arsenic	<0.001	-	mg/L	0.010 mg/L
Barium	0.011	-	mg/L	2.0 mg/L
Beryllium	<0.001	-	mg/L	0.004 mg/L
Cadmium	<0.001	-	mg/L	0.005 mg/L
Chromium	<0.001	-	mg/L	0.1 mg/L
Mercury	<0.001	-	mg/L	0.002 mg/L
Nickel	<0.001	-	mg/L	-
Selenium	<0.001	-	mg/L	0.05 mg/L
Thallium	<0.001	-	mg/L	0.02 /L

[1]Samples collected 9/22/2011

*BDL is Below Detectable Limit, TSS is Total Suspended Solid, TOC is Total Organic Carbon, DOC is Dissolved Organic Carbon

CONSIDERATIONS

An analysis of the IG test results indicates there are no water quality constituents that require specific treatment. If the IG source were to be classified as GWUDI, treatment as surface water would be required. These treatment requirements are discussed further throughout this report.

SURFACE WATER

Raw water quality samples from Cottonwood Creek were collected from May 24, 2021 through July 26, 2021. The sampling period included peak runoff which occurred on June 5, 2021. Table 5 shows the summary of raw water quality data form Cottonwood Creek.

Table 5 – Summary of Raw Cottonwood Creek Water Quality

Constituent	Mean Value	Range of Values	Unit	Treated Water MCL
Turbidity	1.12	0.781 – 2.03	NTU	Varies
TOC	3.1	2.0 – 4.4	mg/L	-
DOC	2.8	1.7 – 4.3	mg/L	-
Diatoms	3,000,000	-	Organism/100L	-
Other Algae	80,000	-	Organism/100L	-
TSS	<5.0	BDL – 6.0	mg/L	-
TDS	82.0	-	mg/L	-
Fluoride	0.26	-	mg/L	4 mg/L
Total Alkalinity	41.5	32.0 – 50.8	mg/L as $CaCO_3$	-
Bicarbonate	40.2	32.0 – 50.8	mg/L as $CaCO_3$	-
Carbonate	<4.0	BDL	mg/L as $CaCO_3$	-
Total Iron	0.18	0.124 – 0.269	mg/L	0.3 mg/L (SMCL)
Total Manganese	0.01	0.008 – 0.0186	mg/L	0.05 mg/L (SMCL)
Calcium	14.5	-	mg/L	-
Magnesium	2.28	-	mg/L	-

Constituent	Mean Value	Range of Values	Unit	Treated Water MCL
Lead	0.0002	-	mg/L	Action Level = 0.015 mg/L
Specific Conductance	110	-	Umhos/cm @ 25°C	-
Chloride	0.7	-	mg/L	-
Ammonia	0.05	-	mg/L	-
Nitrate	0.06	-	mg/L	10 mg/L
Nitrite	<0.03	-	mg/L	1 mg/L
Orthophosphate (as P)	<0.01	-	mg/L	-
Orthophosphate (as PO4)	<0.01	-	mg/L	-
Total Phosphorus	<0.01	-	mg/L	-
Sulfide	<0.1	-	mg/L	-
UV 254 Transmittance	82.7	-	% T/cm	-
Dissolved Silica	3.4	-	mg/L	-
Sulfate	6.9	-	mg/L	-
Sodium	2.80	2.40 - 3.20	mg/L	-
Antimony	<0.001	BDL	mg/L	0.006 mg/L
Arsenic	<0.001	BDL	mg/L	0.010 mg/L
Barium	0.005	0.0090 - 0.0011	mg/L	2.0 mg/L
Beryllium	<0.001	BDL	mg/L	0.004 mg/L
Cadmium	<0.001	BDL	mg/L	0.005 mg/L
Chromium	<0.001	BDL	mg/L	0.1 mg/L
Mercury	<0.001	BDL	mg/L	0.002 mg/L
Nickel	<0.001	BDL	mg/L	-
Selenium	<0.001	BDL	mg/L	0.05 mg/L
Thallium	<0.001	BDL	mg/L	0.02 /L

[1]Samples collected 9/22/2011

CONSIDERATIONS

Based on the collected water quality data, there are four constituents that would likely need to be addressed in a surface water treatment system: turbidity, total organic carbon (TOC), diatoms and other algae, and iron.

Depending on the treatment process, surface water treatment systems must meet either an absolute finished water turbidity of 5 nephelometric turbidity unit (NTU) with 95 percent of monthly samples less than 1 NTU or an absolute turbidity of 1 NTU with 95 percent of monthly samples less than 0.3 NTU. In either case, the average raw water turbidity of the surface water is above the limits and would need to be reduced through filtration.

TOC can react with disinfectants to create a series of compounds called DBPs that can have long-term health effects with chronic exposure. Part of the prevention of DBP formation is removing TOC prior to disinfection. Particulate organic carbon is more easily removed by settling and filtration. Dissolved Organic Carbon (DOC), which is more difficult to remove, makes up the majority fraction of the TOC in the surface water samples collected. As such, a pretreatment process involving coagulant dosing followed by flocculation and sedimentation will likely need to be included prior to disinfection if surface water is used as a long-term water source.

A surface water pilot using cartridge filters found that rapid filter blinding occurred despite filter feed turbidities that were well within the acceptable range. A particulate analysis performed on the spent cartridge filters found that some combination of diatomaceous and non-diatomaceous algae and minerals is suspected to be the cause of the short filter run times. Diatoms and minerals can be removed through a robust pretreatment process.

Iron can be an esthetic concern in drinking water by creating unpleasant odors and tastes and staining water fixtures when it is oxidized in the distribution system or in household plumbing. Although the raw water total iron concentration was below the SMCL of 0.30 milligram per liter (mg/L), concentrations are high enough to warrant treatment and removal, which can be accomplished by oxidizing the iron to a precipitable form prior to sedimentation or filtration.

Impacts from Natural Disasters

Water from Cottonwood Creek, or any drainage within the Upper Arkansas valley, is susceptible to natural disaster events such as fires, mudslides, and flooding. Given the proximity to heavily forested areas, and historic droughts within the watershed, fires can occur either naturally (i.e. lightning strikes) or manmade. During active burning, ash and contaminants become part of the soil matrix and with limited to no vegetation are prone to runoff into streams, ditches, lakes and reservoirs. After a burn, rainstorms, flooding, and mudslides will result in large sediment transport concentrated ash, contaminants, and nutrients to wash into streams, rivers, and downstream reservoirs, as natural erosion prevention has been removed from the watershed. These materials will ultimately make their way to the raw water sources and WTP treatment processes and can have adverse effects on plant operations and treatment and resulting drinking water quality.

Impacts to water quality and treatment processes is not limited to surface water. Recent studies have found that water quality contaminants, such as heavy metals and radionuclides, that are present in surface water as a result of wildfires, can also have lasting impacts on aquifers and ground water supplies. Specifically, high sediment loads and contaminated water from Cottonwood Creek could have negative effects on the IG production rates, as well as the water quality.

The best way to mitigate risk from wildfires is for the Town to develop plans and strategies for managing watersheds to protect against floods, fires and mudslides and having appropriate water treatment barriers for treating compromised waters. It is recommended that the Town participate in regional efforts to develop a source water protection plan, which may provide guidance in the event of a wildfires or floods. Early warning detection systems on the main stem of Cottonwood Creek and North Cottonwood Creek is one such mitigation effort that will detect targeted water quality parameters (i.e. turbidity, conductivity, pH, temperature). Large sediments loading and high turbidity events can be managed through a robust pretreatment system prior to filtration and disinfection. For radionuclide contamination, a selective media filtration system or reverse osmosis may be needed, depending on the radionuclide species that are present. In addition, special considerations for residuals handling must be made, as the material removed from the drinking water may contain high concentrations of metals and radionuclides and may not be disposed of a municipal landfill.

Another risk associated with wildfires are the presence of perfluorinated compounds in drinking water sources. Perfluorinated compounds include compounds such as perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), as well as other structurally related compounds. PFOS and PFOA are human-made, fully fluorinated, organic compounds that are stable and resist typical environmental degradation processes, resulting in them building up in the environment. PFOs have been used in fire retardant foam which subsequently can leach into water supplies. The Town is in a moderately forested area that could be impacted by forest fires in which fire retardant may be applied.

In May 2016, the Environmental Protection Agency (EPA) established drinking water health advisories of 70 parts per trillion (0.07 micrograms per liter (µg/L)) for the combined concentrations of PFOS and PFOA. Above these levels, EPA recommends drinking water systems take steps to assess contamination, inform consumers, and limit exposure. Although the EPA has not issued a MCL for drinking water for PFOS and PFOA, several states have established drinking water and groundwater guidelines. Colorado has yet to establish these guidelines.

SECTION 3 – TREATMENT ALTERNATIVES

This section explores pretreatment, treatment, and disinfection alternatives that can treat the Town's raw water to comply with the Regulations and meet the Town's goals which are:

- Supply high quality water to the Town's customers
- Have reliable and redundant water supply and treatment system
- Maintain a Class B operator requirement, if possible
- Limit operations and maintenance (O&M) costs and capital cost

Shown in Table 6 is a summary of treatment alternatives for both IG and surface water that will be considered in this Section.

Table 6 – Treatment Alternatives for IG and Surface Water

Water Source	Pretreatment	Treatment Filtration	Disinfection
Infiltration Gallery Alone	Not required	• Cartridge • Dual/Mixed Media • Membranes	• Ultraviolet Radiation • Chlorine (liquid, tablet, on-site generation)
IG & Surface Water	• Pre-Oxidation (Fe, Mn) • Direct Coagulation • Flocculation / Sedimentation	• Direct Filtration • Dual/Mixed Media • Membranes	• Ultraviolet Radiation • Chlorine (liquid, tablet, on-site generation)

The IG water is high quality and does not require pretreatment. However, treatment and disinfection will be required. The surface water from Cottonwood Creek will require pretreatment, in addition to filtration and disinfection. Design calculations for the treatment alternatives are included in Appendix B and equipment information is included in Appendix C.

PRETREATMENT ALTERNATIVES (FOR SURFACE WATER)

Pretreatment processes target constituents in the water that cannot be removed by filtration alone. Pretreatment processes generally include chemical addition, and/or flocculation and sedimentation prior to a filtration process downstream. Enhanced settling processes may be implemented to increase contaminant removal and filter runtime. They can also provide a buffer during turbidity spikes that may occur during spring runoff or that may happen as a result of flooding, mudslides, or fires upstream of the WTP intake.

The surface water from Cottonwood Creek has elevated levels of iron, TOC, and subject to high turbidity events which must be pretreated prior to filtration. Pretreatment alternatives to remove these constituents are explored below.

For conventional treatment systems with TOC greater than 2.0 mg/L, TOC removal shall comply with the percent removal shown in Table 7, which is taken from Regulation 11, Section 11.24. TOC removal is recommended for systems that have detected TTHMs and HAA5s concentrations greater than the MCL of 0.080 mg/L and 0.060 mg/L, respectively, in the distribution system. The

TOC percent removal requirements based on source water TOC and source water alkalinity are summarized in Table 7.

Table 7 – TOC Removal Requirements

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as CaCO3)		
	0-60	>60-120	>120
	Required Step 1 TOC Percent Removal		
>2.0-4.0	35.0	25.0	15.0
>4.0-8.0	45.0	35.0	25.0
>8.0	50.0	40.0	30.0

The surface water's TOC concentration ranges between 2.0 mg/L and 4.4 mg/L and the alkalinity ranges from 32.0 mg/L as $CaCO_3$ to 50.8 mg/L as $CaCO_3$. The Town would be required to achieve 35 percent to 45 percent TOC removal depending on the TOC concentration.

Alternative 1 – Pre-oxidation

Pre-oxidation includes adding an oxidant chemical to the raw surface water which will help with treating the TOC and iron in the Cottonwood Creek surface water. The chemical would be injected upstream of the main treatment processes and oxidized constituents would be removed through a downstream settling or filtration process.

Three oxidants were evaluated to target the removal of TOC and iron: Potassium permanganate, sodium permanganate, and chlorine dioxide. Permanganates are useful in oxidizing iron, manganese, taste and odor compounds, and are beneficial in controlling nuisance organisms, and control of formation of DBPs by oxidizing precursor compounds, such as TOC, and reducing the demand for additional disinfection downstream. Potassium permanganate is a solid powder and requires batching to a 2 to 3 percent solution by the operator. Sodium permanganate is delivered in liquid form. Approximately 1 mg of permanganate is required to oxidize 1 mg of iron in the raw water. The resultant dosing for either permanganate is anticipated to be between 0.1 and 1.0 mg/L, based on preliminary raw water quality information. Jar testing would be required to determine the seasonal optimal dosing range, as well as TOC removal rates. Permanganate can require up to 30 minutes of contact time to fully oxidize the targeted constituents.

Chlorine dioxide is also useful in oxidizing iron and TOC. It has a much faster, nearly instantaneous reaction time, however, it results in production of chlorite and chlorate ions, which are disinfection byproducts. Approximately 1.2 mg of chlorine dioxide is required to oxidize 1 mg of iron in the raw water. The resultant dose for chlorine dioxide would be between 0.2 and 1.0 mg/L. Jar testing would be required in order to determine the optimal dosing range for oxidant selection. A summary of the advantages and disadvantages for each oxidant is provided in Table 8.

Table 8 – Pre-Oxidation Alternatives Analysis

Alternative	Advantages	Disadvantages
Potassium Permanganate	• Lowest chemical cost • May be delivered in liquid or powdered form	• Longest reaction time • Largest contact volume requirements • Highest capital cost • Limited effectiveness for TOC
Sodium Permanganate	• Chemical delivered as a liquid, reducing chemical makeup time as compared to potassium permanganate • Faster reaction rate than potassium permanganate • Reduced contact volume	• Higher O&M and delivery cost than potassium permanganate • Limited effectiveness for TOC removal
Chlorine Dioxide	• Effective for TOC removal • Instant oxidation reaction, minimal contact volume required • Powerful Oxidant and Disinfectant. • Smaller footprint	• Chlorite monitoring required • Highest O&M cost • Potential to increase DBPs during summer months (chlorite)

ALTERNATIVE 2A – COAGULATION (DIRECT FILTRATION)

Coagulation is the addition of a coagulant chemical to target TOC and turbidity removal. The coagulant is injected upstream of the main treatment process and mixed into the raw water. Mixing can be induced via a static mixer or rapid mixer depending on the main treatment process that follows. For direct filtration, the majority of precipitated constituents are filtered out by the main treatment process.

Direct coagulation and filtration is not a recommended option for treating surface water from Cottonwood Creek, as it contains high levels of TOC in dissolved form, iron, and diatoms. In addition, the surface water is subject to turbidity spikes during spring runoff events that will lead to low filter run times and reduce the efficiency of the filtration process.

ALTERNATIVE 2B – COAGULATION WITH FLOCCULATION AND SEDIMENTATION (CONVENTIONAL FILTRATION)

The main difference between conventional treatment and direct filtration is the inclusion of the flocculation and sedimentation process for removal of flocculated particles prior to filtration and reducing the formation potential of Disinfection Byproducts (DBPs) associated with TOC and chlorine. With certain raw water quality, flocculation and sedimentation will reduce TOC and particulates of concern prior to filtration and allow for increased filter run times.

After a coagulant is added to the raw water, raw water enters a flocculation basin. Flocculation basins consist of two to four basins in series, each equipped with a mixing device or paddle wheel such that the mixing intensity decreases from basin to basin, inducing floc formation. After flocculation, water enters a sedimentation process. A sedimentation process includes slowing down the velocity of water moving across a basin. By slowing down the water, the floc can settle to the bottom of the basin and be removed by a collection system. The sedimentation process can be improved by installing plate settlers into the basin. Plate settlers decrease the basin footprint and volume required to effectively settle the floc, significantly reducing capital cost and improving resiliency.

Figure 5 – Plate Settlers

Jar testing with three different coagulants was conducted on July 20, 2021, to determine optimal doses and removal efficiencies for TOC. The three coagulants evaluated include Sodium Aluminate ($NaAlO_2$), Aluminum Chlorohydrate (ACH, Nalco 8187), and PACL (Nalco 8134). The jar testing results indicated that ACH was the most effective coagulant for removing TOC using direct filtration. For additional information see the Pilot Study Report.

Alternative 3 – Pre-sedimentation Pond

Pre-sedimentation ponds are a low maintenance method that can be used to settle large particulates out of the raw water prior to treatment. These ponds are generally sized to decrease the velocity of the water prior to treatment to promote settling. However, dissolved contaminants and smaller microorganisms are not settled out unless pre-sedimentation is combined with other pretreatment alternatives. The Town has an existing pre-sedimentation pond with a weir that also helps settle out larger sediment.

Table 9 provides an analysis of the advantages and disadvantages of the pretreatment alternatives. The recommended pretreatment alternative can be one or more of the alternatives discussed.

Table 9 – Pretreatment Alternative Analysis

Alternative	Advantages	Disadvantages
Pre-oxidation	• Lowest construction cost • May be constructed outside of building • Easy operation • Low annual O&M	• Largest footprint • Highest detention time for sedimentation process • Limited TOC • No *Giardia* credit
Coagulation (Direct Filtration)	• Lowest construction and O&M cost • Smallest Footprint • Can be installed now and integrated in later with Flocculation / Sedimentation	• Limited TOC and turbidity removal • No credit for *Giardia* Inactivation • Difficult to control dosing

Alternative	Advantages	Disadvantages
Coagulation with Flocculation and Sedimentation	• Most reliable • Able to treat turbidity over 500 NTUs • Very effective for TOC removal • 0.5 log inactivation for Giardia • Handles varying water quality	• Larger Footprint • Higher capital and O&M costs • Produces a sedimentation residuals
Pre-sedimentation	• Low maintenance and cost • Allows for raw water equalization and blending and discrete particle settling	• Less reliable for particulate removal • Larger footprint • May have algae growth • No *Giardia* inactivation credit

Treatment Alternatives (For IG and Surface Water)

Since it is anticipated the IG will be reclassified as GWUDI the Regulations require a filtration step similar to Cottonwood Creek. Filtration is a physical barrier such as mixed media, membranes, or cartridges. These three alternatives are explored below. Note that any alternative that can effectively treat surface water can also treat IG water.

Alternative 1 – Mixed Media Filtration

The Town is familiar with mixed media filtration from the abandoned WTP. It is possible to repurpose the four basins (two filter basins and two flocculation basins) for mixed or dual medial filtration. All four basins are of identical size (12 ft x 12 ft) and depth and are common wall to the existing filter gallery. More current technology utilizes molded plastic underdrains with lower profile and air scour rather than surface wash. The existing vertical turbine pump that provides backwash supply will need to be replaced along with expansion of the existing backwash recovery ponds. The existing flocculation basins will need to be outfitted with media and piping penetrations to match the other two filters. The clearwell could be repurposed for chlorine contact and backwash supply.

Based on historic operations for treating surface water, mixed media filtration will require pretreatment for particulate and precursor removal for increasing filter run times and reducing backwash volumes and waste. Historically, the mixed media filters had short run times, requiring operating staff to spend the night during certain times of the year to meet water demand. The frequent filter clogging is likely due to the large quantity of diatoms and algae discovered in the Cottonwood Creek surface water. Their removal through sedimentation will improve mixed media filter run times.

Proprietary packaged treatment units are available that offer coagulation, contact adsorption clarification and filtration with a significantly smaller footprint compared to conventional treatment systems. However, CDPHE classifies these proprietary packaged systems as direct filtration systems because they do not meet design criteria for flocculation and sedimentation hydraulic retention times.

ALTERNATIVE 2 – MEMBRANES

There are two main types of membrane filtration processes that may be considered for the Town's surface water and IG source: pressure and gravity. Pressure Membrane Filtration (PMF) are defined as an applied or mechanical (pump or vacuum) that forces or pulled through a hollow fiber to create a permeate or filtered effluent. Gravity Membrane Filtration (GMF) does not require an applied or mechanical force to draw water through a hollow fiber to create a permeate of filter effluent, much like a mixed or dual media filter system.

Figure 6 – Gravity Membrane

GMF is a process of removing particulate and organisms from a raw water source by straining water through a hollow membrane filter using gravity rather than a pressure gradient. Most GMF systems are considered ultrafilters (UF), which have a pore size of 0.04 micron which requires a backwash and air scour 1 to 2 times per day, depending on raw water quality. Gravity filter membranes do not require a chemical clean, or clean in place systems. Typical surface loading rates for GMFs is 6 to 8 gallons per day per square foot (gpd/ft2)

PMF systems remove particulate and organisms from the raw water stream by straining the raw water through a hollow fiber using an applied (pressure or vacuum) pressure gradient. Similar to GMF, most PMF systems are UF with an effective pore size opening of 0.04 microns. Typical UF transmembrane pressures range from 20 to 30 PSI. PMF technology is relatively consistent across manufacturers and most manufacturers can provide customizable skids depending on the owner's preferences for ancillary equipment, capacity, and operational flexibility. An advantage of GMF and vacuum applied PMFs over pressure (forced) applied PMF, is that, since submerged, modules can be installed within existing basins for retrofitting existing WTPs. Typical surface loading rates for PMFs is 25 to 35 gpd/ft2. GMFs also do not require clean-in-place (CIP) and maintenance wash chemicals compared to PMFs for restoring and minimizing irreversible fouling. GMFs are backwashed with finished water with chlorine injection and air scour, similar to mixed media filters.

ALTERNATIVE 3 – CARTRIDGE FILTERS

Cartridge filters are a simple technology that consists of a housing and modular filters. They use pressure from pumping or gravity flow to push the water through the modular filters. The modular filters are made with a microfiber media designed in an accordion or pleated pattern to maximize surface area for treatment. A 100 gpm cartridge typically has a filter surface area of 120 square feet. The cartridge filter pores are specifically sized to remove cyst-sized particles from the raw water, which are 1 to 2 microns, so they generally are best suited to target the removal of microorganisms. The cartridges come in various sizes ranging from 0.35 to 150 microns, depending on the raw water quality. A typical installation would consist of a cartridge with a larger pore size, often referred to as a prefilter, followed by a filter with a smaller pore size, the compliance filter, in series.

In order for cartridge filters to comply with Regulation 11 for surface water systems, it must be demonstrated that the turbidity entering into (influent) the compliance filters is less than or equal to 1.49 NTU. One or more of the following methods may be submitted as proof:

1. Turbidity results – A minimum of one turbidity reading per week from March through June showing raw water turbidity or pretreatment turbidity reliably achieving less than 1.49 NTU.
2. Pilot/demonstration study – A pilot or demonstration with the proposed compliance cartridge filter showing the ability to reliably achieve less than 1.49 NTU downstream of the compliance filter for at least one month during the critical or most challenging period.
3. Particulate removal study – A minimum of weekly results from particulate studies showing the ability to reliably achieve less than 1.49 NTU prior to the compliance filter for at least a two month period during critical or most challenging period.

Figure 7 – IG Pilot Setup

A pilot scale study was performed to determine if cartridge filtration is a viable option to comply with Regulation 11 for the Town's surface water source. During the pilot study the turbidity of the prefiltered water did not exceed 1.49 NTU. However, the surface water compliance filter still experienced rapid fouling and the differential pressure consistently increased to 30 psi within 24 hours. As indicated in the surface water quality discussion in Section 2, it is suspected that the rapid filter fouling was caused by a combination of algae and minerals in the raw water. Additionally, higher TOC concentrations in the raw surface water would require coagulation and flocculation, which would create even greater particulate loading on cartridge filters and further decrease cartridge life. For these reasons, cartridge filtration is not recommended for surface water. However, it is a viable treatment alternative for the IG water because of the higher raw water quality.

Advantages and disadvantages for each filtration treatment alternative is provided in Table 10.

Table 10 – Filtration Treatment Alternative Analysis

Alternative	Advantages	Disadvantages
Pressure Membrane Filters (PMF)	• Comparative lower equipment cost • Ability to use pretreated raw water as backwash supply • Potential for treating surface water using direct coagulation / filtration	• Would require significant building modifications or new building • Highest annual O&M cost • Highest total project cost • Requires clean in place system • Require pumping • Requires Class A Certification

Alternative	Advantages	Disadvantages
Gravity Membrane Filters (GMF)	• Existing WTP building and filter / floc basins can be modified to fit filters • Potential for treating surface water using direct coagulation / filtration • Lowest total project cost • No chemical clean system required • No pumping required	• Requires air scour system • Requires additional storage in clearwell for backwash water • Requires Class A Certification
Cartridge Filtration	• Lowest O&M cost • Lowest equipment costs • No chemicals • Simple process and does not require Class A operation certification	• Not suitable for surface water
Mixed Media Filtration	• Moderate O&M costs (less than PMF and GMF • Simple Operations and operator familiarity • Low chemical usage (filter aid) • Existing WTP filter and floc basins could be used with an expansion	• Must have conventional pretreatment upstream to be effective • Requires addition storage in clearwell for backwash water
Proprietary Filtration Systems	• Modular and cost effective • Has some pretreatment with adsorption clarification	• Higher chemical usage compared to conventional filtration systems • Only 2.0 log removal for Giardia

DISINFECTION ALTERNATIVES (FOR IG AND SURFACE WATER)

The Town currently utilizes chlorine gas for disinfection. Due to operational issues, and health and safety concerns, the Town would like to consider an alternative disinfection system. Three alternative chlorine disinfection systems are evaluated below. In addition, Ultraviolet (UV) radiation is evaluated to supplement chlorine disinfection. UV can reduce the amount of chlorine and the contact time for Giardia and Virus log removal.

CHLORINE DISINFECTION

Chlorine is the most common disinfectant for public water systems because it is readily available, cost effective, and maintains a residual in the distribution system. The three chlorine alternatives explored below are bulk liquid sodium hypochlorite, calcium hypochlorite, and onsite generated sodium hypochlorite.

ALTERNATIVE 1 – SODIUM HYPOCHLORITE

Sodium hypochlorite, NaOCl, is the most widely used chemical for disinfection in Colorado. It is available in various solution concentrations but most often, a 10 or 12.5-percent solution is used for municipal application. At a 12.5-percent concentration, sodium hypochlorite has 12 to 20-percent of available chlorine. Most municipal treatment entities can receive cost-competitive pricing for chemicals when full tanker trucks are delivered on a regular basis. The standard capacity for a bulk tanker truck is approximately 4,500 gallons. The Town would use an estimated 1,400 gallons per month of 12.5-percent sodium hypochlorite at a flow rate of 80-percent of 2.5 MGD for 30 days.

Sodium hypochlorite is typically dosed with a chemical metering pump that introduces the hypochlorite into the process via injection quills inserted into a pipe. The pumps can be paced by inputs from a programmable logic controller (PLC) either on a flow or target chlorine residual basis or both such that the dose rate changes automatically with changes in process flow or chlorine demand.

Disinfection with sodium hypochlorite for a 2.5 MGD plant would require a Class C Water Treatment Operator license. Sodium hypochlorite is classified as a corrosive material and building codes require hazardous (H) occupancy requirements for storage of over 500 gallons. H-occupancy requirements include continuous ventilation, fire barriers, fire sprinklers, secondary containment, and backup power.

Alternative 2 – Calcium Hypochlorite

Calcium hypochlorite, $Ca(OCl)_2$, is commonly used in smaller facilities and is available in a tablet form or powder that is dissolved in water prior to application. In solution, it has 65 to 70-percent available chlorine. Calcium hypochlorite tablets typically come in 50-lb pales. While tablet or powder storage does not require secondary containment, a 2.5 MGD plant may require up to 15 pales per month.

Figure 8 – Chlorine Dosing Equipment

Calcium hypochlorite dosing is often achieved via a tablet contactor, in which a stack or pile of tablets is submerged in the process flow. The water dissolves the tablets, introducing hypochlorous acid into the water. The contactors are typically designed such that higher flowrates result in greater submergence of the tablets so that a dose rate proportional to flow is maintained.

Disinfection with calcium hypochlorite for a 2.5 MGD plant would require a Class C Water Treatment Operator license. Calcium hypochlorite is classified as a corrosive materials. However, H-occupancy requirements are only required when storage exceeds 5,000-pounds.

Alternative 3 – Onsite Hypochlorite Generation

An alternative to receiving deliveries of chlorine chemicals is to generate a low-strength sodium hypochlorite on site using salt brine and electricity. This way the Town would not be reliant on a third party for chemical deliveries and operations staff would not be exposed to hazardous chemical storage or transportation. In contrast with sodium and calcium hypochlorite dosing, on-site hypochlorite generation requires regular maintenance of the equipment and salt handling.

Disinfection with on-site sodium hypochlorite for a 2.5 MGD plant would require a Class B Water Treatment Operator license. Onsite sodium hypochlorite generators create a 0.8 to 1-percent solution of sodium hypochlorite which is not considered to by corrosive so no H-occupancy requirements would apply.

ULTRAVIOLET LIGHT

UV light can be used to supplement chlorine disinfection. UV light of a certain frequency disrupts the DNA of pathogenic microorganisms and prevents them from reproducing and causing disease. With improvements of the technology, UV has become a popular and cost-effective approach to disinfection. UV consists of installing a pressurized bank of UV lights in a closed pipe system.

Some important considerations when using UV for disinfection is that while it is effective at deactivating larger pathogenic microorganisms in water, such as Giardia Lamblia, it is less reliable for deactivating smaller ones, such as viruses. Furthermore, UV does not have any lasting disinfecting action after initial contact. For both of these reasons, UV is typically used for primary disinfection and must be followed by secondary chemical disinfection using chlorine for viral removal and to create a residual chlorine concentration to prevent contamination in the distribution system.

Typical maintenance tasks include initiating and/or monitoring clean-in-place cycles, and cleaning and replacing the UV lamps and sleeves. Despite this maintenance, a UV system could reduce the required volume of a chlorine contact chamber to such a degree that it could prove cost effective. For example, installing UV to meet the additional 0.5-log Giardia disinfection required for cartridge filtration results in reducing the clearwell volume by approximately 60,000-gallons. Disinfection with Ultraviolet Light for a 2.5 MGD plant would require a Class C Water Treatment Operator license.

Advantages and disadvantages for each disinfection alternative is provided in Table 11. UV filtration must be combined with one of the other disinfection alternatives since it does not provide a residual.

Table 11 – Disinfection Alternatives Analysis

Alternative	Advantages	Disadvantages
Chlorine Alternatives		
Sodium Hypochlorite	• Easily adjustable dosing • Consistent concentration • Easy redundancy	• Secondary containment required • Hazardous occupancy • Tends to form leaks in dosing piping • Requires bulk liquid deliveries
Calcium Hypochlorite	• Safer to Handle • Shelf Stable • Cheapest capital and operating cost	• Contributes hardness to water • Less dose control for high or low chlorine demand situations
On-Site Hypochlorite Generation	• Easily adjustable dosing • Consistent concentration • Independent from chemical deliveries • Non-hazardous	• Highest capital cost • Complex system using electrolysis

Alternative	Advantages	Disadvantages
UV (Potentially Used in Conjunction with the Selected Chlorine Alternative)		
UV	• Reduces DBP creation • Decreases contact volume required for Giardia inactivation	• Not a stand-alone solution. Needs to be paired with chlorine for virus inactivation and residual in the distribution system • High capital cost • High power requirements • Requires regular maintenance

Fluoridation Treatment Alternatives (IG and Surface Water)

Fluoridation treatment is the addition of fluoride to water to promote healthy teeth and reduce cavities. The Department of Human Health and Services (HHS) and Center for Disease Control and Prevention (CDC) recommends a concentration of 0.7 mg/L. This limit was changed from the previously recommended range of 0.7 mg/L to 1.2 mg/L in 2015.

According to the EPA, fluoride in concentrations above the MCL of 4.0 mg/L may cause bone disease and pain and tenderness of the bones and mottled teeth in children. According to the EPA, fluoride concentrations above the SMCL of 2.0 mg/L may cause tooth discoloration. Finished water with fluoride concentrations exceeding 2.0 mg/L require the operator in responsible charge (ORC) to notify customers that the water may not be safe for children. The Town’s raw water fluoride concentration is 0.14 mg/L in IG and 0.26 mg/L in the surface water.

Fluoridation is not a treatment process required for potable water systems and the decision to include it is often dependent on the community.

Alternative 1 – Fluoridation System

This alternative includes the addition of fluoridation system. There are three main chemicals that are commonly used for fluoridation including: sodium fluoride, fluorosilicic acid, and sodium fluorosilicate. Each additive has a different solubility and characteristics that require different feed systems.

Fluorosilicic acid is the most common form of fluoridation. It is a liquid that is also referred to as hydrofluorosilicate, FSA, or HFS. Fluorosilicic acid has the simplest fluoridation system which requires a chemical tank, a metering pump, a platform scale, and an anti-siphon device. Fluorosilicic acid is infinitely soluble and therefore only a metering pumps is required to feed into the water system.

Sodium fluoride is a crystalline or powder additive that must be dissolved in a solution before it is added to finished water. Sodium fluoride is typically used by smaller water systems as it is easily handled. It is typically more expensive than other fluoridation additives. Sodium fluoride solubility is around 4 percent for typical water temperatures. A special device called an upflow saturator is used to feed sodium fluoride. A saturated solution is created by passing water through a bed containing sodium fluoride. A feed pump then injects the sodium fluoride saturated solution into the water system. If the water passing through the upflow saturator has a hardness greater than 50 mg/L it must be softened prior to passing through the upflow saturator. This is a much more operationally intensive system and requires more equipment as compared to fluorosilicic acid system.

Sodium fluorosilicate is also referred to as sodium silicofluoride, which is a powder additive that must be dissolved in a solution prior to mixing with finished water. This feed system would require dry chemical storage area, day tank and mixing system, a metering pump, a platform scale, and an anti-siphon device.

Dry feed systems can be used for sodium fluorosilicate and sodium fluoride. Dry feeder systems are designed to feed dry powered chemicals at a predetermined rate and can be metered by volume or by gravity. Volumetric dry feeders are easier to operate, are less expensive, deliver small quantities, and are less accurate compared to gravimetric dry feeders which are capable of delivering large quantities of dry chemical, are more expensive, and are more accurate. Typical volumetric dry feeders use a rotating feed screw that moves a set volume of material from the hopper to the mixing tank where a mechanical mixer will mix the material with water. There are two types of gravimetric feeders, the first type is based on weight loss of the hopper, and the second is based on the weight of the material on a section of belt. The material is then deposited into a mixing tank like the volumetric dry feeder and mixed with water. Dry material is dangerous to load and requires the operators to suit up in additional personal protective equipment (PPE) while handling the chemical. Due to the hazards associated with the dry chemicals, it would be recommended to have a separate, designated area for the fluoride feed system with improvements to the ventilation system.

Fluoridation requires a Class B operator certification at a plant capacity of 2.5 MGD. Since these chemicals are hazardous, H-occupancy building code requirements will apply.

ALTERNATIVE 2 – NO FLUORIDATION

No fluoridation is the simplest alternative for the Town. The Town currently does not fluoridate and it is not a required treatment process by the Regulations. This alternative would not accrue the Town any capital and O&M costs. In addition, the Town's surface water from Cottonwood Creek has an average fluoride concentration of 0.26 mg/L, which provides some level of oral health benefit.

Advantages and disadvantages for each fluoride alternative is provided in Table 12.

Table 12 – Fluoridation Alternatives Analysis

Alternative	Advantages	Disadvantages
Fluoridation	• Potential dental health benefits	• Fluoride has an SMCL and MCL • High capital cost • High O&M cost • Hazardous material
No Fluoridation	• No capital or O&M costs	• No potential dental benefits

Alternative Screening

The alternatives were screened using the decision matrices shown in Table 13, Table 14, and Table 15. Each criteria is weighted based on importance and scores of one through five are given to each alternative with five being the highest score possible. Qualitative criteria were selected based on what is believed to be the most important considerations by the Town for selecting treatment alternatives for both IG and surface water. Capital cost was not used as a criterion for the screening with the understanding that the selected qualitative factors are the primary drivers for treatment selection. Annual costs were considered since that is an important factor for the Town as it relates to chemical usage, equipment maintenance, energy costs, and operation staffing. Each of the criterion are defined as follows:

O&M Costs: Annual costs that include chemicals, energy, labor, maintenance, repairs, replacement for operating the source water and treatment system

Land Area Requirement: Added land area (Town owned or acquired) that is needed for the source water, conveyance and treatment systems

Reliability and Resiliency: Measure of consistency and predictability for high quality source water and robust treatment systems to meet water quality objectives

Compatibility: Measure of similarity and familiarity with existing source water, conveyance and treatment systems the Town currently operates and maintains now and into the future

Operator Certification Requirement: Certification level required to operate and maintain the treatment systems in accordance with Regulation 100

Health and Safety: How safe are the treatment systems to operate and maintain? Systems that use more chemicals and mechanical equipment will have more protocols for health and safety and actions taken compared to less complex systems using lower and potentially less hazardous chemicals

Table 13 – IG Treatment Alternatives

Criteria	Weight	Treatment		
		Cartridge Filters	Mixed Media Filters	Membranes
O&M Cost	10%			
Land Area Requirement	10%			
Reliability / Resiliency	10%			
Compatibility	30%			
Operator Certification Requirement	20%			
Health and Safety	20%			
TOTAL	100%			

Table 14 – Surface Water Treatment Alternatives

Criteria	Weight	Pretreatment				Treatment	
		Pre-oxidation	Coagulation (Direct Filtration)	Coagulation, Flocculation, Sedimentation (Convention Filtration)	Pre-sedimentation	Mixed Media Filters	Membranes
O&M Cost	10%						
Land Area Requirement	10%						
Reliability / Resiliency	10%						
Compatibility	30%						
Operator Certification Requirement	20%						
Healthy and Safety	20%						
TOTAL	100%						

Table 15 – Disinfection Alternatives

Criteria	Weight	Disinfection		
		Liquid Chlorine	Tablet Chlorine	OnSite Generation
O&M Cost	10%			
Hazard and Safety	10%			
Operator Certification Requirement	10%			
Compatibility	30%			
Resiliency	20%			
Footprint and Storage Requirement	20%			
TOTAL	100%			

SECTION 4 – PROJECT ALTERNATIVES

This section discusses the alternatives to treat either the IG water or Cottonwood Creek surface water. The Cottonwood Creek surface water quality as described in previous sections will require some level of pretreatment prior to filtration for meeting drinking water regulations and reliable treatment operations. Any treatment process that works for surface water will be acceptable for the IG water. Considerations for operator certification, reliability / resiliency health and safety, operations and maintenance, and capital cost are discussed for each source recommendation.

INFILTRATION GALLERY ALTERNATIVE

From a water quality perspective, the IG is the preferable water source. Pretreatment for IG water is not needed due to the historically high water quality throughout the year. The IG source water has been serving the Town since 1974 and has never exceeded secondary and primary drinking water standards. The IG infrastructure in Gorrel Meadows will need to be expanded to meet the maximum production flowrate of 2.5 MGD. Recommended improvements to the IG supply, treatment, and disinfection are detailed below. A preliminary process flow diagram (PFD) and layout are shown in Figure 10 and Figure 11.

SUPPLY

Hemenway Groundwater Engineering's (HGE) Report in included in Appendix D. As indicated in HGE's report, some operational changes could be made to the current IG to increase short term production to help cover high demand days and weeks. However, it is not anticipated that these changes will be able to supply the full 2.5 MGD that the Town needs. In order to meet this flowrate, a new infiltration gallery will need to be designed and installed. This would provide the needed flowrate and some redundancy, but not complete redundancy since the existing IG cannot supply the max capacity on its own.

Figure 9 – Deep Trenching Technology

According to HGE, two new IG laterals installed in Gorrel Meadows east of the existing IG will increase IG production to 2.5 MGD. The new laterals will be located so their construction minimizes disruption to the existing IG. The laterals will be installed at a depth of 20 feet and consist of perforated high density polyethylene (HDPE) pipe. The horizontal pipe will convey the water to a large diameter vertical pipe wetwell equipped with a submersible or vertical turbine pump that will pump the water to the new WTP building. Refer to the HGE report for details.

A new transmission pipe will be installed below Cottonwood Creek to convey the water from the new IG laterals. The new IG will function as a completely separate system from the existing IG, allowing for some redundancy if either IG fails or is taken offline for maintenance. The proposed new IG laterals are shown in Figure 11.

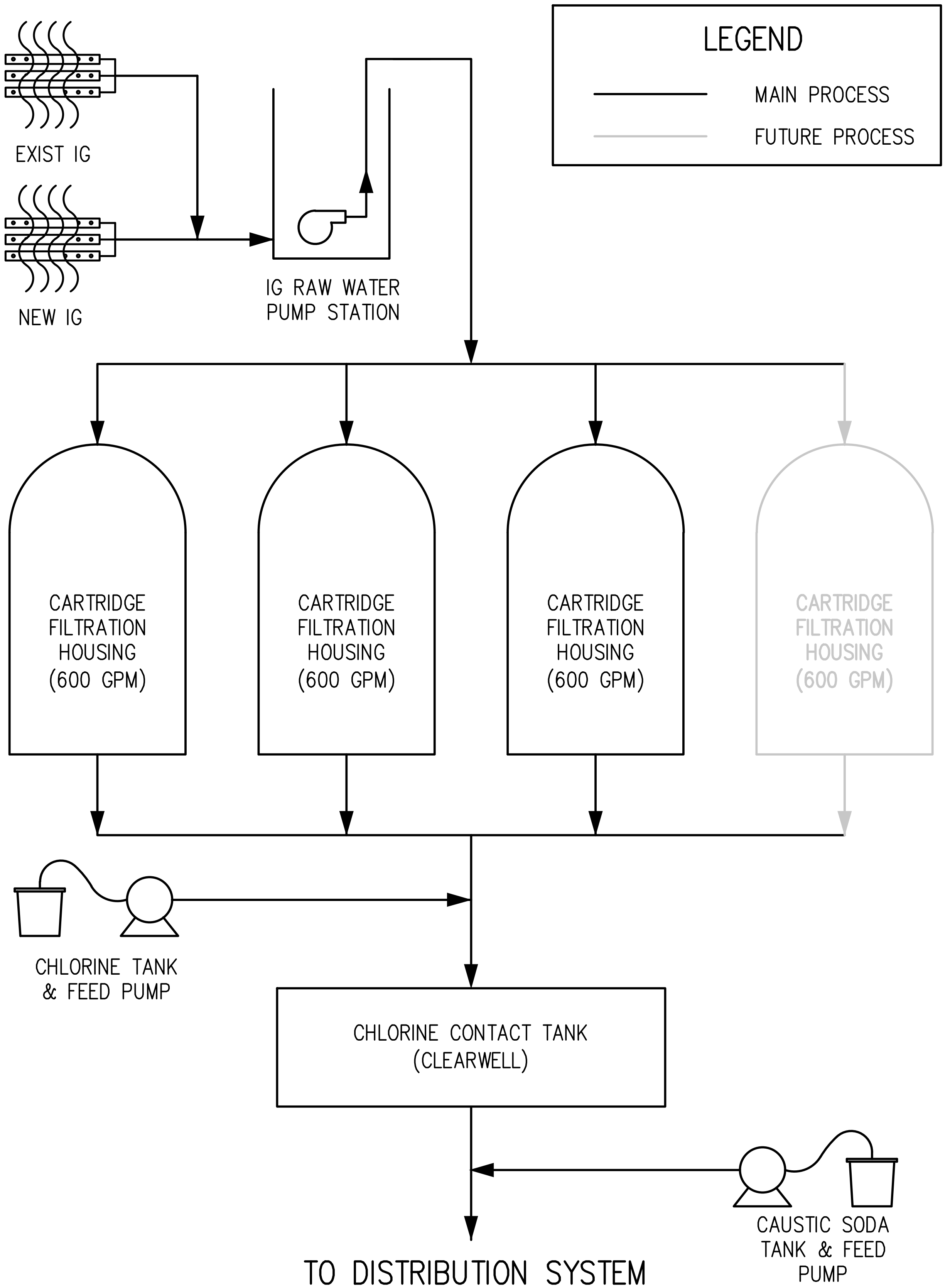

FIGURE 10 - PROPOSED IG IMPROVEMENTS PFD

TOWN OF BUENA VISTA

SEPTEMBER 2021

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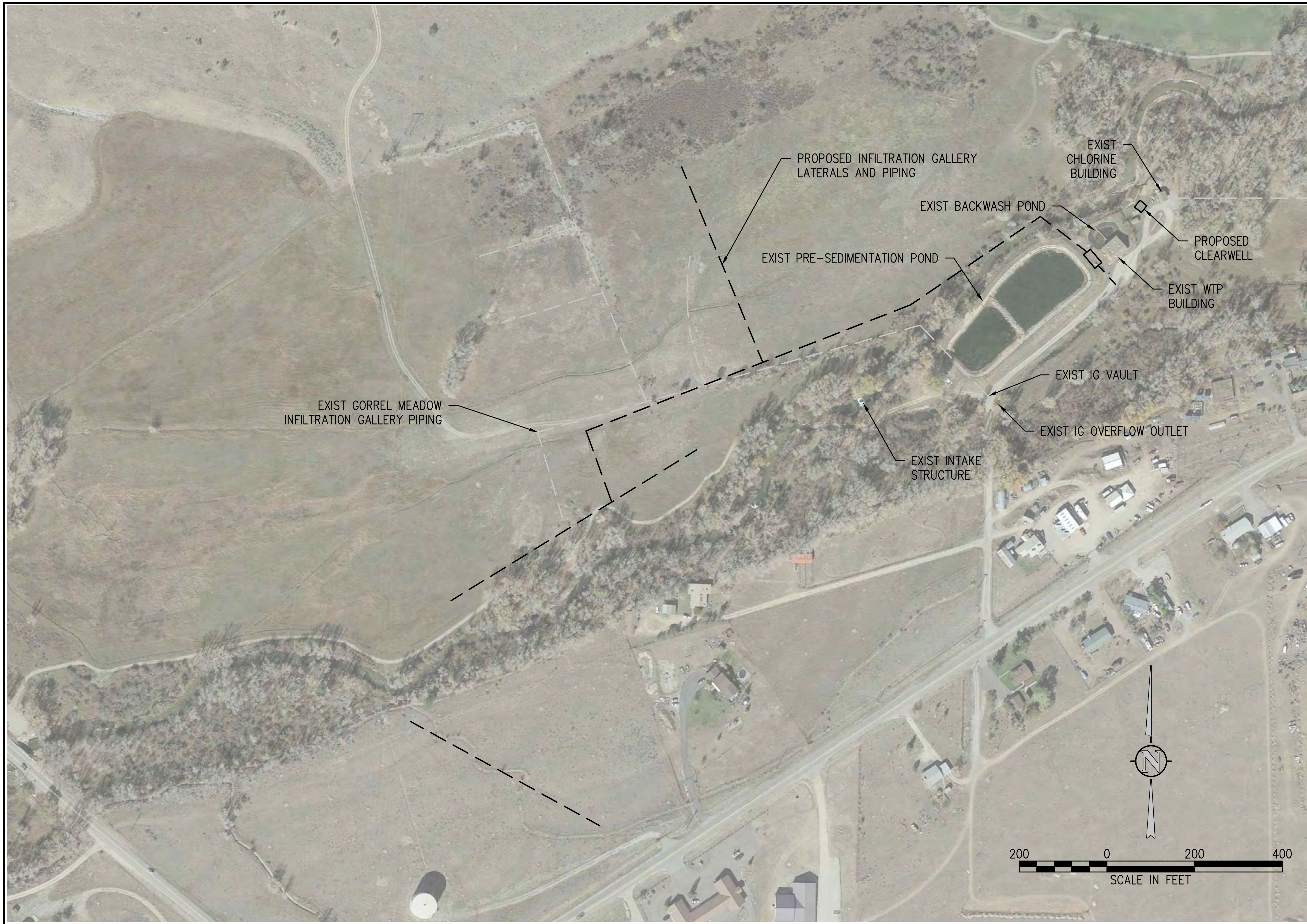

FIGURE 11 - PROPOSED IG IMPROVEMENTS LAYOUT

TOWN OF BUENA VISTA

SEPTEMBER 2021

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TREATMENT

Water from the existing and expanded IG will be networked and conveyed to a raw water pump station located at the WTP site. The raw water pump station will pump the IG water to an array of cartridge filters located in a new building. The filtration booster pumps will contain variable frequency drives (VFDs) that ramp the pumps up and down to maintain a designated flowrate through the filters as headloss develops in the filter cartridges. The flowrate of these pumps will be set by the operators to accommodate system water demands. After filtration, chlorine is added to the filtered water and directed to clearwell for disinfection contact time.

Harmsco MUNI-8-6FL filter housings are recommended for this treatment system. Each housing accommodates eight HC/170-LT2 filter cartridges, each with a recommended flow rate of 75 gpm for *Giardia lamblia* removal. This equates to a recommended flowrate of 600 gpm, or 0.864 MGD per filter housing. Four of these housings operating in parallel will provide a firm capacity of 2.59 MGD, with three housings online and one offline housing to be rotated into service as needed for repairs or cartridge replacement in another housing.

The design criteria for a cartridge filtration treatment system for use in treating IG water are shown in Table 16.

Table 16 – Design Criteria for Cartridge Filtration

Parameter	CDPHE Design Criteria	Proposed Design
Cartridge Housing	CDPHE Pre-Approved	Harmsco MUNI-8-6FL
Maximum Housing Capacity	N/A	800 gpm each
Recommended Housing Capacity	N/A	600 gpm each
Number of Housings	N/A	4
Max Capacity	Capacity with all units online	3.46 MGD
Firm Capacity	Capable of treating maximum flow with one unit offline	2.59 MGD
Cartridge Filters Per Housing	N/A	8
Filter Cartridge	CDPHE Pre-Approved	HC/170-LT2
Differential Pressure	Must not exceed maximum specified from third party validation	30 psi max based on manufacturer recommendation
Turbidity Monitoring	Individual filter skid turbidity and combined effluent filter turbidity	Yes
Differential Pressure Monitoring	Testing method specified	Built in pressure gauges cartridge housing
Filter Change Out Requirements	Protocol specified and records	Yes
	Filters must be used once and then discarded with no backwashing of chemical cleaning	Yes
Sample Taps	Influent and effluent	Yes
Check Valve	After filter vessel	Yes
Pressure Relief Valve	Inlet to each vessel	Yes
Flow Metering	Yes	Yes
Flow Control	Yes	Yes

Parameter	CDPHE Design Criteria	Proposed Design
Protection from water hammer and pressure surges	Yes	Yes

Clearwell and Disinfection

Chlorine addition to the filtered IG water is required to achieve disinfection. Since cartridge filtration receives a 2.5-log Giardia credit, the remaining 0.5-log Giardia and 4.0-log virus disinfection can be achieved using a minimum 80,000 gallon clearwell, assuming a pH of 8.0, a temperature of 10°C, a baffle factor of 0.6, a 1 mg/L chlorine residual, and a production rate of 2.5 MGD. To allow for operations flexibility a minimum 105,000 gallon clearwell is recommended.

Onsite sodium hypochlorite generation is recommended. Onsite generation minimizes the storage and handling of hazardous chemicals in the form of sodium or calcium hypochlorite. Similarly, the onsite generation requires only salt as a consumable, which is much more readily available than the other two disinfection chemicals described in Section 3. This would make the Town more self-reliant in the event of any kind of a shortage or transportation delay. Clearwell and disinfection design criteria are presented in Table 17.

Table 17 – Disinfection Design Criteria

Parameter	CDPHE Design Criteria	Propose Design
CLEARWELL		
Overflow and Drain	Required	Yes
Vents	Open downward, above accumulated snow depth, and screened	Yes
Access	Opening elevated 24" above top of clearwell with water/insect tight gasket, locked	Yes
Redundancy	Design must allow for clearwell to be taken offline for routine cleaning and maintenance. The system is a single treatment facility with less than 3 days for storage in the distribution system, two parallel trains must be provided.	Yes, two trains
DISINFECTION		
Maximum free chlorine residual	5 mg/L	2.0 mg/L
Standby equipment	Sufficient capacity to replace largest unit/ spare parts available	Yes
Required treatment	3-Log removal of Giardia lamblia, 4-Log removal of viruses	2.5-Log/3-Log Giardia removal provided by filtration (Cartridge/Membrane); 0.5-Log Giardia (Cartridge only) and 4-Log virus removal provided in clearwell.
Continuous chlorine residual monitor	Required	Yes

Parameter	CDPHE Design Criteria	Propose Design
CHEMICAL APPLICATION		
Backflow prevention devices provided	Required	Yes
ANSI/NSF 60	All chemicals are ANSI/NSF Standard 60 approved	Yes
Secondary containment provided	Required	Yes
Redundant feeder provided	Required	Yes
Automatic or manual control options	Required	Yes
Feed rate proportional to flow	Required	Yes

pH Adjustment

The IG raw water pH is approximately 6.9. The Town uses caustic soda (sodium hydroxide) to increase the pH to between 7.6 and 7.8. A new caustic soda storage tank and feed system will be required for the expanded WTP. The chemical feed system will include duty and standby metering pumps with a capacity of 1.3 gph, assuming a dosing rate of 4.0 mg/L. The Town will use an estimated 750 gallons per month of 25 percent caustic soda at a flow rate of 80 percent of 2.5 MGD for 30 days.

Considerations

Considerations to operator certification, WTP production capacity, WTP resiliency, operations and maintenance, and capital cost for the recommended IG improvements are discussed below.

Operations Certification

For the recommended IG expansion, the maximum operator certification requirement will be a Class B. For a 2.5 MGD flow, both the cartridge filtration and the onsite hypochlorite generation will require a Class B license. For a flow under about 2.0 MGD, the certification requirements will drop to Class C licenses.

Production

According to HGE, the recommended improvements to the IG infrastructure will provide 2.5 MGD of raw water to the WTP.

Reliability and Resiliency

In addition to the flow considerations discussed above, using two infiltration galleries for the Town's sole water supply also provides less resiliency than including treatment capabilities for the surface water source. The most feasible location for a new infiltration gallery is just down gradient of the existing gallery. Furthermore, additional potential locations on the Town's property are not far removed from the existing gallery. In the event of a groundwater contamination event that affected the Town's water supply, it is likely that all infiltration galleries in the area would be impacted. Meeting the Town's water needs with expansion and addition to the infiltration gallery therefore meets redundancy for repair and maintenance situations but not necessarily for groundwater contamination events. However, the groundwater supply is less likely to be impacted by natural disasters such as fires and mudslides that could affect Cottonwood Creek. The Town currently diverts surface water onto the IG from North Cottonwood Creek during higher demand periods. By expanding the IG, it is likely that this practice may no longer be needed saving the staff time and reducing maintenance. It also reduces the possibility of introducing contaminants that may be present in the surface water onto the IG. If diversion off North Cottonwood Creek is still necessary, it is recommended that an early warning water quality detection system be installed upstream to allow operators notification of when not to divert water.

Operation and Maintenance

Operationally, a groundwater cartridge filtration system will be simpler than a surface water treatment system. Operations will consist primarily of monitoring headloss through the filters, as well as influent and effluent turbidity. The most labor-intensive task will be the periodic replacement of the filter cartridges, which is assumed to occur every eight weeks.

Assuming an annual average WTP production rate of 1.38 MGD, the estimated annual and 20-year O&M cost for the proposed treatment processes is $79,033 and $1,551,300 respectively. The O&M cost are included in Appendix E.

Capital Cost (OPC)

The capital cost for the proposed treatment processes is estimated to be $5,127,500 including design and engineering. The OPCs are included in Appendix E.

Cottonwood Creek Surface Water Alternative

Having the ability to treat raw water from Cottonwood Creek creates the most resilient water supply, because the processes required to treat the surface water can also be used to treat IG water. Treating surface water requires the more capital improvements. The existing diversion and intake structure on Cottonwood Creek will need replaced and the existing pre-sedimentation ponds will need to be rehabilitated. Pretreatment will be necessary due to the TOC and iron, and the surface water susceptibility to environmental events. Recommended improvements to the Cottonwood Creek supply, pretreatment, treatment, and disinfection are detailed below. A preliminary process flow diagram (PFD) and layout are shown in Figures 13 and 14.

Figure 12 – Cottonwood Creek

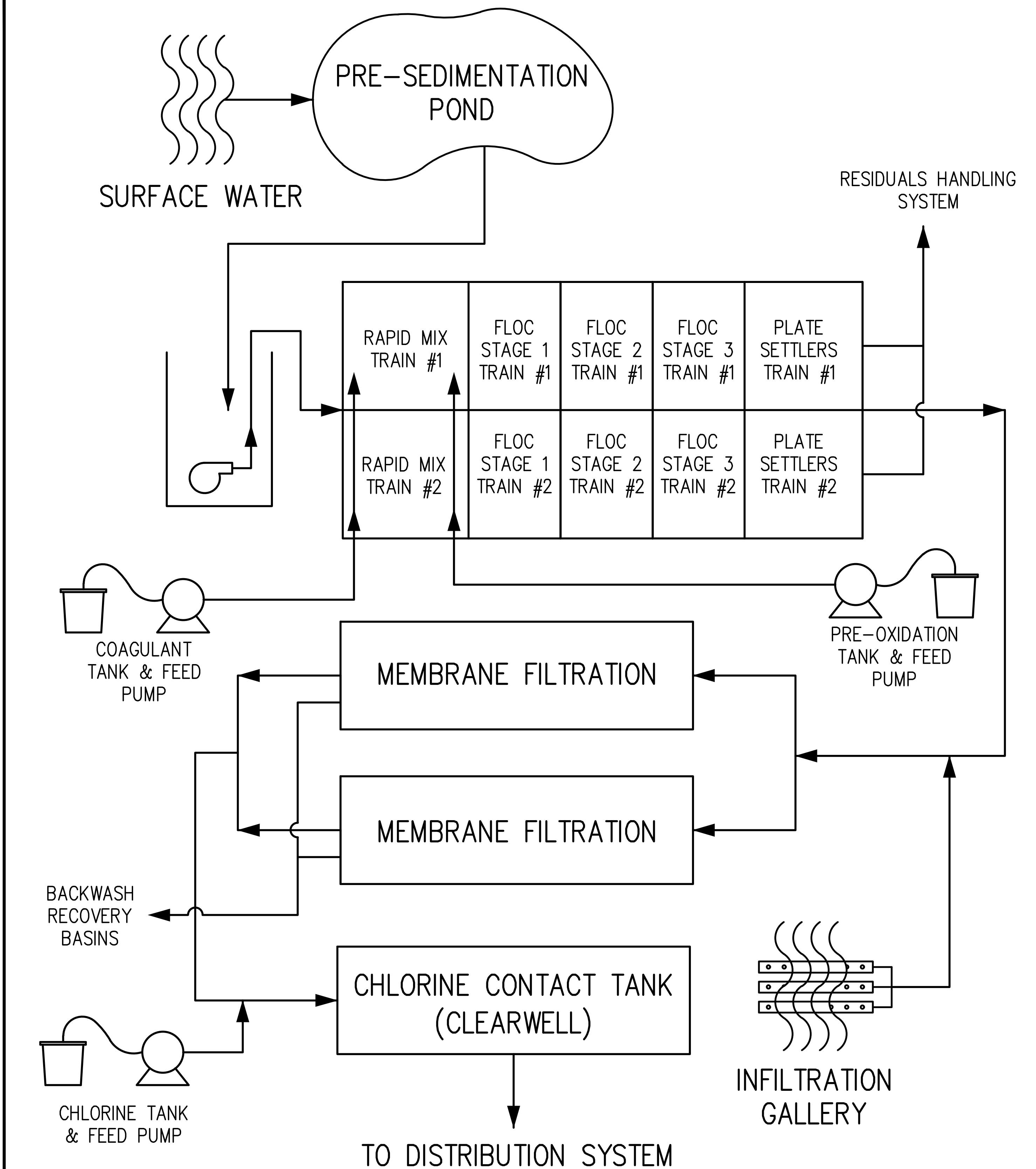

FIGURE 13 - SURFACE WATER PROPOSED PFD

TOWN OF BUENA VISTA PDR

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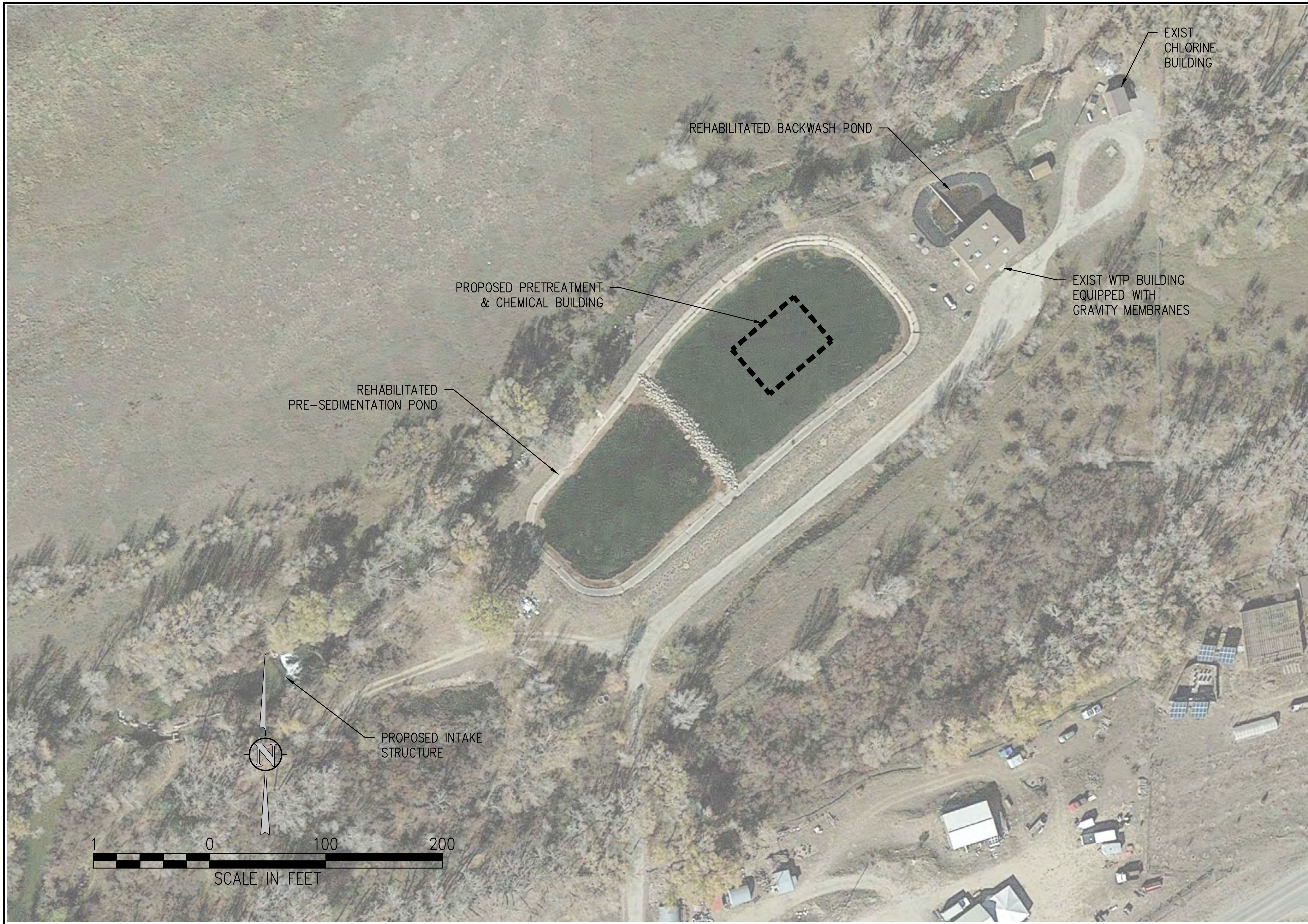

FIGURE 14 - PROPOSED SURFACE WATER IMPROVEMENTS LAYOUT
TOWN OF BUENA VISTA PDR
SEPTEMBER 2021

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1319 Spruce Street
Boulder, CO 80302
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JVA CONSULTING ENGINEERS

Supply - Headgate and Diversion

A new headgate and diversion is recommended due to the condition of the existing infrastructure. Erosion and sedimentation are design considerations for a new headgate and diversion. The structure should not impound water in channel upstream of the dam. This reduces the impacts from sediment pulses that may supply the creek from upstream erosion. High flows flush sediment downstream from the structure and reduce impacts to the pre-sedimentation ponds and the upstream channel.

The new headgate and diversion will include a natural channel design. The design will include a decreased step height to allow for fish passage and increased stability of the structure during high flow events. A series of boulder or concrete steps with a maximum 1-foot of elevation raise per step will dissipate energy and allow fish passage.

Pre-sedimentation Pond

Improving and reusing one of the existing pre-sedimentation ponds is recommended. The cell will be cleaned and regraded prior to installing a new impermeable liner. All valves and piping from the Cottonwood Creek intake structure to the pond will be evaluated and replaced as necessary. The overflow back to Cottonwood Creek will be rehabilitated to return any surplus water. The footprint of the second pre-sedimentation pond will be used for a new pretreatment process.

Pretreatment

The recommended pretreatment alternative is pre-oxidation and coagulation with flocculation and sedimentation. Potassium permanganate will be used to oxidize iron and TOC. Coagulation with flocculation and sedimentation will enhance the removal of iron and TOC and increase the resiliency of the WTP to handle environmental events such as fires or mudslides.

The equipment needed for a potassium permanganate pre-oxidation are chemical storage tanks, chemical feed pumps, and suitable contact time. Contact time for iron oxidation can be up to 30 minutes and achieved in a flocculation basin or dedicated contact basin. The equipment needed for coagulation addition are chemical storage tanks and chemical feed pumps. Both will require rapid mixing. Design criteria for chemical pretreatment is provided in Table 18.

Table 18 – Design Criteria for Pretreatment Chemical Addition

Parameter	CDPHE Design Criteria	Propose Design
Design Flow	N/A	2.5 MGD
Coagulant	ANSI/NSF 60	Nalco 8187 ACH
Coagulant Concentration	N/A	60%
Coagulant Dose	N/A	10 mg/L
Coagulant Storage Required	1.5 truckloads minimum	933 gallons minimum for 30 days of storage
Coagulant Chemical Feed Rate (100-percent solution)	Feed equipment must be capable of maximum and minimum feed ranges	18.8 gpd

Parameter	CDPHE Design Criteria	Propose Design
Coagulant Minimum Velocity Gradient (G value)	500 $second^{-1}$	Yes
Coagulant Mixing	Device must provide adequate mixing at all flow rates	Yes
Flow Split	If yes, means of measuring and modifying flow to each train must be provided	No flow split for coagulation
Oxidant	N/A	Potassium Permanganate
Oxidant Concentration	N/A	3 %
Max Oxidant Dose	N/A	2 mg/L
Oxidant Storage Required	1.5 truckloads minimum	1,850 gal minimum for 30 days of storage
Oxidant Chemical Feed Rate (100-percent solution)	Feed equipment must be capable of maximum and minimum feed ranges	0.92 gpd
Chemical Pump Type	N/A	Peristaltic
Chemical Pump Quantity	Redundancy	2 total per chemical, 1 duty, 1 standby
Chemical Backflow Prevention or back-siphonage	Between multiple points of feed through common manifolds	Yes
Chemical Reaction Time	Yes	Yes
Chemical Containment	For liquid storage tanks over 55 gallons	Yes
Chemical Tank Drain	For liquid storage tanks over 55 gallons	Yes
Chemical Tank Vent	For liquid storage tanks over 55 gallons; no common vents	Yes
Chemical Tank Level	Yes	Yes

Flocculation and sedimentation is recommended after pre-oxidation and coagulation using two trains. Each flocculation train will consist of three basins, each equipped with a paddle wheel and over-under baffles. Water will flow from the final flocculation basin to a sedimentation basin equipped with plate settlers. Settled water flows from the plate settlers to the next treatment process, while settled solids are collected and sent to a residuals handling process. Table 19 shows conceptual design criteria for flocculation and sedimentation with plate settlers.

Table 19 – Design Criteria for Flocculation and Sedimentation

Parameter	CDPHE Design Criteria	Propose Design
Design Flow (per Train / design / buildout)	N/A	2.5 MGD
FLOCCULATION		
Basin Dimension (L x W x D) per Train	Design should minimize short circuiting	15 ft. x 15 ft. x 16 ft. side water depth
Number of Flocculation Stages per Train	Minimum 2	3
Minimum Flocculation Detention Time at Design Flow	30 min	45 minutes

Parameter	CDPHE Design Criteria	Propose Design
Mechanical Agitation	If used must provide decreasing energy	Yes
Velocity of flocculated water	Greater than 0.5 and less than 1.5 feet per second through pipes or conduit	11" to 18" diameter pipe
SEDIMENTATION		
Basin Dimension (L x W x D) per Train	Provided for dewatering	40 ft. x 15 ft. x 16 ft. side water depth
Plate Loading Rate	Maximum of 0.7 gpm/ft2	0.3 gpm/ft2
Head Loss through System	N/A	2.5 ft
Solids Removal Concentration	N/A	0.5 to 2.0 -percent
Sludge Flow Per Collector	N/A	150 to 200 gpm
Hose bibs	For washdown and maintenance	Yes
rate of flow over outles weirs	Must not exceed 20,000 gpd/ft2 of outlet launder	Yes
Plate Loading Rate	Maximum of 0.7 gpm/ft2	0.3 gpm/ft2

TREATMENT

Gravity membrane filters (GMF) are the recommend alternative for surface water to reduce turbidity to below 0.1 NTU and to remove constituents of concern and pathogens. GMF can be placed into the existing filter basins with minimal design changes to the existing tanks. The preliminary design criteria for a GMF is shown in Table 20. It is important to note the number of gravity membrane modules is flexible based on preference and manufacturer recommendations as design proceeds. Another advantage of GMF is that it is more forgiving for treating surface water without robust pretreatment meaning that GMF can be used for both IG and surface water with minor pretreatment improvements (i.e. pre-oxidation) and potentially phasing in future pretreatment facilities.

Table 20 – Design Criteria for Membrane Filters

Parameter	CDPHE Design Criteria	Propose Design
Design Capacity	N/A	2.5 MGD
Initial Capacity per Skid	N/A	580 gpm
Membrane Flux	Design flux and basis for flux selection must be provided in the BDR.	Based on manufacturer recommendation
Raw/Feed/Source Water Quality	Raw water analysis as stated in Item 1.2.3 to justify membrane design and pre-treatment steps	Yes
	Clear identification of source raw water quality	Yes
Raw/Feed/Source Water Quality	Quality of feed water to the membrane system used to rate capacity	Yes
Pre-treatment chemicals compatibility	Statement of Compatibility between membrane material and upstream processes	Yes

Parameter	CDPHE Design Criteria	Propose Design
Maximum Transmembrane Pressure (psi)	Must not exceed maximum as specified in specific membrane acceptance list	Based on manufacturer recommendation
Turbidity Monitoring	Turbidity monitoring on combined filter effluent and individual membrane units	Yes
Turbidity Performance Standards	0.1 NTU 95% of time, not to exceed 0.5 NTU for each skid and combined effluent	Yes
Integrity testing	Direct integrity testing method with failure criteria clearly delineated	Yes
Repair of Broken Fibers	Protocol for report of broken fibers shall be provided	Yes
Membrane Pretreatment - Strainer	Strainer system prior to membrane system to protect the fiber. Identify mesh size and provide function description including operation, headloss recovery, and method to handle waste stream	Based on manufacturer recommendation
Influent and effluent sampling taps	Required	Yes
Appropriate pressure measurement for TMP and direct integrity testing	Required	Yes
Meter indicating instantaneous flow	Required	Yes
Online turbidimeters on the effluent line for each unit	Required	Yes
Flow rate controller to control membrane flux on each unit	Required	Yes
Membrane Pretreatment - Strainer	Strainer system prior to membrane system to protect the fiber. Identify mesh size and provide function description including operation, headloss recovery, and method to handle waste stream	Based on manufacturer recommendation
Influent and effluent sampling taps	Required	Yes
Appropriate pressure measurement for TMP and direct integrity testing	Required	Yes
Meter indicating instantaneous flow	Required	Yes
Online turbidimeters on the effluent line for each unit	Required	Yes
Flow rate controller to control membrane flux on each unit	Required	Yes
Control System -Backup System	Automated monitoring and control system must be provided and consist of:	Yes
	Spare PLC loaded with most current program or dual running PLC with synchronized programs	Yes
	Backup power supply for PLC	Yes
Control System - automatic shutdown process	Include automatic shutdown processes for:	Yes

Parameter	CDPHE Design Criteria	Propose Design
	High raw or filtrate turbidity	Yes
	Pump failure	Yes
	High pressure decay test	Yes
	High TMP	Yes
Redundancy	Membrane system redundancy (along with disinfection)	Yes
BACKWASH		
Backwash General	Description of backwash protocol including frequency, duration of events, mechanism for backwashing, backwash water supply, and basis of the approach	Based on manufacturer recommendation
Backwash Chemicals	Identification of backwash chemicals used	Based on manufacturer recommendation
Backwash Supply and Waste	Description of backwash supply and waste and disposition at completion of backwash	Yes

CLEARWELL AND DISINFECTION

Chlorine addition to the filtered surface water is required to achieve disinfection. Since membranes receive a 3-log Giardia credit, the remaining 4.0-log virus disinfection can be achieved using a minimum 18,000 gallon clearwell, assuming a pH of 8.0, a temperature of 10°C, a baffle factor of 0.6, a 1 mg/L chlorine residual, and a production rate of 2.5 MGD. To allow for operations flexibility a minimum 25,000 gallon clearwell is recommended. The existing 33,000 gallon clearwell has sufficient capacity to achieve disinfection contact time if baffles and inlet and outlet diffusers are added to obtain a 0.6 baffle factor.

Onsite sodium hypochlorite generation is recommended. Onsite generation minimizes the storage and handling of hazardous chemicals in the form of sodium or calcium hypochlorite. Similarly, the onsite generation requires only salt as a consumable, which is much more readily available than the other two disinfection chemicals described in Section 3. This would make the Town more self-reliant in the event of any kind of a shortage or transportation delays. Clearwell and disinfection design criteria are presented in Table 17 above.

BACKWASH PONDS

Solids from the high-rate sedimentation process will be transported to backwash ponds for settling, thickening, and storage for eventual disposal. The existing backwash ponds will be used for this purpose. The ponds will need to be rehabilitated with new inflow and outflow piping and pumps, restorative grading, and new liners. The pumps will recycle clear supernate to the head of the pre-sedimentation pond. The backwash waste water could also to be discharged to Cottonwood Creek which would require a surface water discharge permit. The Town does not currently have an existing surface water discharge permit and would need to apply for one. As needed, solids will be pumped into tanker trucks and hauled offsite for disposal. If the infiltration gallery is used as a primary water source, solids accumulation is expected to be minimal and require very infrequent pumping.

CONSIDERATIONS

Considerations to operator certification, WTP production capacity, WTP resiliency, operations and maintenance, and capital cost for the recommended Cottonwood Creek surface water improvements are discussed below.

OPERATOR CERTIFICATION

For the recommended surface water treatment system, the required operator certification requirement would be a Class A. For 2.5 MGD production, both coagulant addition and membrane filtration will require a Class A license, while the permanganate dosing and onsite hypochlorite generation will require Class B. For a flow less than 2.0 MGD, the certification requirements would drop to Class B and Class C licenses for the respective processes.

PRODUCTION

There is typically sufficient flow in Cottonwood Creek to supply the 2.5 MGD, as long as the Town's water rights permit.

RESILIENCY

Incorporating the capacity to treat either 2.5 MGD of water from Cottonwood Creek or the infiltration gallery provides the most resiliency possible because the alternative source can be used if either groundwater or surface water becomes unavailable for use.

OPERATION AND MAINTENANCE

As indicated by the higher operator certification requirements, the proposed surface water treatment system would represent significantly more complex operations and maintenance than the cartridge filtration system. Pretreatment chemical dosing, of potassium permanganate and coagulant require dosing calculations and regular jar testing to ensure the proper balance between effective dosing and chemical usage. The rapid mixers, flocculators, and high-rate settling basins include motors and many moving parts that would require periodic greasing and parts replacement. The membrane filtration involves the fine tuning of numerous setpoints and periodic cleanings of different intensities.

The estimated annual and 20-year O&M cost for the proposed treatment processes is \$110,625 and \$2,347,300, respectively. The O&M cost are included in Appendix .

CAPITAL COST (OPC)

The capital cost for the proposed treatment processes is estimated to be \$12,751,000. The OPCs are included in Appendix E.

PRIORITIZATION AND PHASING

The IG water quality is superior. If the Town intends to install treatment for Cottonwood Creek surface water but rely on IG water as the primary raw water source, the Town may consider not installing flocculation and sedimentation at this time. Membranes will effectively treat IG water, and membranes with pre-oxidation and coagulation will effectively treat Cottonwood Creek surface water most of the year. By removing the flocculation and sedimentation processes, the WTP will not remove as much TOC and will be more susceptible to environmental events such as fires and mudslides.

The main concern with not removing sufficient TOC is that the chlorine could react with the TOC to form DBPs in the distribution system. However, DBPs compliance is based on a rolling annual average, so if the Town uses surface water for one month of the year, while the IG is offline, the rolling annual average will most likely remain below the MCL. The risk of environmental impacts is decreased if the Town can treat both IG water and Cottonwood Creek surface water. If an environmental event impacts Cottonwood Creek, the Town could use IG water.

By not installing flocculation and sedimentation now, the Town could reduce the cost of a surface WTP. The WTP will not be as resilient, but it should be adequate if the IG is the primary water source for the majority of the year. The surface WTP can be designed for the addition of flocculation and sedimentation in the future, if the Town begins to rely more on Cottonwood Creek surface water.

If the Town chooses to treat the IG water through cartridge filtration, a Class C operator license is required while the WTPs rated capacity is below 2.0 MGD. If the WTP rated capacity expands to 2.5 MGD, a Class B operator license is required. If the Town chooses to treat surface water, a Class B operator license is required while the WTP’s rated capacity is below 2.0 MGD and licensing requirements will change to Class A once the rated capacity expands to 2.5 MGD.

SECTION 5 – PROJECT RECOMMENDATION

The WRMP recommends the Town should have the ability to treat IG and surface water to allow for maximum redundancy and flexibility to provide water for the Town's customers. The IG provides high quality water that requires minimal treatment and is more resilient against natural disasters, while the surface water is more predictable in terms of capacity and can provide reliable redundancy. Installing a new IG will not provide full redundancy to the water system because the existing IG does not have a 2.5 MGD capacity while the surface water source requires pretreatment in order to remove constituents of concern. By including IG and surface water improvements in the final recommended project, the Town may choose to use the more pristine IG source the majority of the time while still having the flexibility to use the surface water when the IG capacity is not sufficient. A preliminary process flow diagram (PFD) and layout are shown in Figure 15 and Figure 16, respectively.

The project recommendation includes a 2.5 MGD firm capacity WTP that will be initially approved for 2.0 MGD capacity. By designing for a larger firm capacity but permitting for a lower capacity, the Town is able to keep a Class B ORC license until the WTP demand exceeds 2.0 MGD. Once the water demand is near 2.0 MGD, the Town can apply for a rate increase and become permitted for a 2.5 MGD plant without having to complete capital projects to increase the capacity of the WTP. The ORC will also need to have a Class A license when the Town applies for a rate increase.

INFILTRATION GALLERY SUPPLY

Installing a new IG will increase capacity from Gorrel Meadows to 2.5 MGD. As discussed in Section 5, the new IG will be comprised of laterals made of HDPE pipe installed at a depth of 20 feet. The new IG will be a completely separate system from the existing IG, which will provide some redundancy for the Town.

COTTONWOOD CREEK SURFACE WATER SUPPLY

A new intake structure at Cottonwood Creek will include a new headgate and diversion. As described in Section 4, the new headgate and diversion will have a natural design that will allow for fish passage, maintain the stability of the structure, protect from erosion and reduce impacts to the pre-sedimentation pond and upstream channel.

PRETREATMENT

Pretreatment will include pre-sedimentation pond improvements, pre-oxidation and direct coagulation. A full flocculation and sedimentation system can be installed in the future, if needed or as Town relies more on surface water.

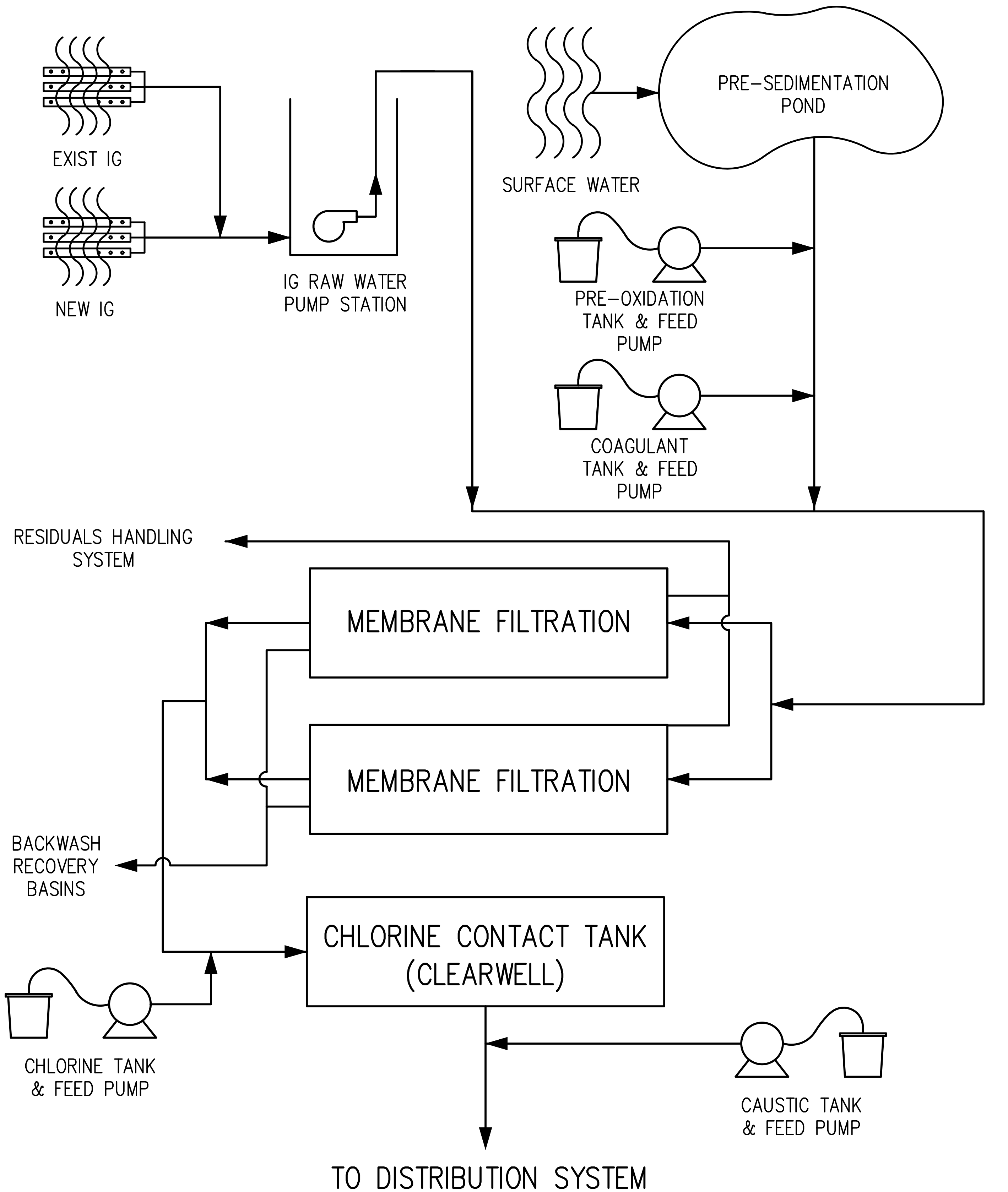

FIGURE 15 - PROPOSED PROJECT PFD
TOWN OF BUENA VISTA PDR
SEPTEMBER 2021

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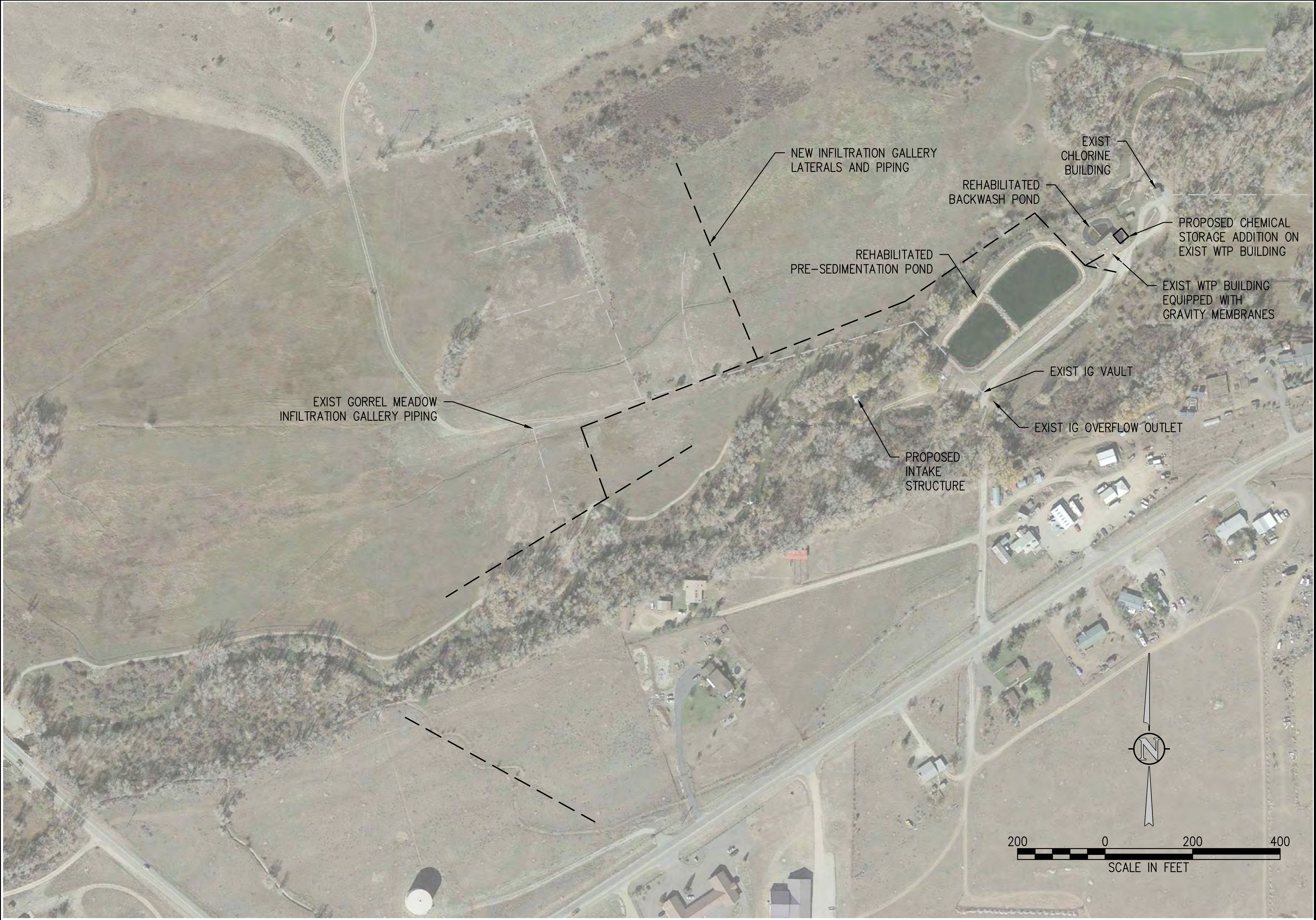

FIGURE 16 - PROPOSED PROJECT LAYOUT

TOWN OF BUENA VISTA

SEPTEMBER 2021

JVA CONSULTING ENGINEERS

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The pre-sedimentation pond will be rehabilitated with a new liner. Any necessary improvements to the valves and piping from the intake structure to the pre-sedimentation pond will be included. Potassium permanganate will be used to oxidize iron and TOC. ACH coagulant will be used to remove iron and TOC.

Treatment

Gravity membranes will be installed for treatment filtration so the Town will have the ability to treat surface water, as discussed in Section 4. The gravity membranes will be installed in the existing concrete basins in the existing WTP building, reducing construction costs. Water from the IG and the surface water will combine in a pipeline and gravity flow to the membranes.

Clearwell and Disinfection

The existing 33,000 gallon clearwell has sufficient capacity to achieve 4-log removal of virus inactivation since gravity membranes will be installed. The existing clearwell does not have any baffles. Baffles will be installed to increase the baffling factor in the clearwell, thereby increasing the capacity of the clearwell. An onsite sodium hypochlorite generator will be installed for disinfection. As discussed in Section 4, the materials necessary for onsite generation are more readily available than other disinfection chemicals. Only one onsite sodium hypochlorite generation system will be installed, with space for a future onsite generator. Rather than a redundant onsite generation system, the Town can store 10-percent liquid sodium hypochlorite solution onsite in 55 gallon or smaller drums as backup. Spare parts for the single sodium hypochlorite system will be stored onsite.

The filtered water from the membranes will be dosed with sodium hypochlorite prior to gravity flowing into the existing clearwell.

pH Adjustment

As discussed in Section 4, caustic soda will be added to adjust pH when the Town is utilizing IG water. The chemical feed system will consist of a duty and standby pump system and bulk storage tank. From the clearwell, the treated water will flow by gravity to the distribution system.

Capital Cost (OPC)

The capital cost for the recommended treatment processes is estimated to be $11,317,000. The OPCs are included in Appendix E.

SECTION 6 – IMPLEMENTATION

This section explores permitting, equipment preselection, construction manager at risk (CMAR) project delivery method, and anticipated schedule to implement the recommended improvements.

CDPHE DESIGN CRITERIA AND PERMITTING

In accordance with the Regulations, the CDPHE Engineering Section reviews and approves drawings and specifications relating to new or modified WTPs. CDPHE reviews for compliance with Policy 5 – Design Criteria for Potable Water Systems (Design Criteria).

Permitting with CDPHE requires submission of a Basis of Design Report (BDR) in accordance with the Design Criteria. This submission will include all required forms, design calculations, and an updated opinion of probable cost. The BDR includes project and system information, sources of potential contamination, water quality data, process flow diagrams and hydraulics profiles, a capacity evaluation and design calculations, a monitoring and sampling evaluation, a geotechnical report, residuals handling, a preliminary plan of operation, impacts to corrosivity, and other supplemental or pertinent information, along with 60-percent drawings and specifications. The CDPHE Appendix B: BDR Template will be included with the submission and stamped by a licensed Professional Engineer. JVA will review the BDR with the Town and incorporate any comments into the packet prior to submission to CDPHE. JVA will respond to CDPHE requests for information and incorporate CDPHE comments into the final design.

EQUIPMENT PRESELECTION

Pre-selection of the major process equipment is recommended to expedite the overall schedule, reduce conflicts during construction, and provide the highest level of equipment design input from the Town. Pretreatment, filtration, and chemical delivery equipment is recommended for pre-selection.

JVA will work with the Town to pre-select the major process equipment through a formal competitive process. Formal Request for Proposals (RFPs) will be advertised to qualified manufacturers with preliminary drawings and specifications for the proposed improvements. JVA will tabulate the proposals and review with the Town to make a firm selection. Before finalizing the scope and cost from the manufacturer, the drawings and specifications will be developed to a minimum 30 percent level and modifications of the proposal will be negotiated with the selected manufacturer to meet the final design capacities, layout, and specific design features for the Buena Vista WTP.

After selection of the major process equipment, the final proposals with scope of supply, performance guarantee, and cost will be incorporated into the Pre-selected Equipment specification section of the Project Manual and incorporated into the 60 percent drawings to be submitted to CDPHE for BDR approval.

CONSTRUCTION MANAGER AT RISK (CMAR) PROCESS DESCRIPTION

The proposed delivery method is Construction Manager at Risk (CMAR). This is a delivery defined by the Design Build Institute of America (DBIA). Generally, it is a commitment by a general contractor to deliver the project within a defined schedule and price. The CMAR delivery process helps to separate and mitigate risk and responsibility for all parties. The general contractor is at the table with the owner and engineer to help value engineer and provide constructability suggestions in real time prior to construction. The engineer represents the owner during the process to negotiate with the contractor and refine the drawings and specifications per the value engineering and constructability efforts. The CMAR contractor will bid the project to subcontractors and in an open book process share these prices to the owner and engineer. Generally, subcontractors are selected based on best value. The preconstruction efforts of the CMAR, Town, and engineer culminate in a guaranteed maximum price (GMP). The GMP is open book and will be based on the decisions made during the value engineering and constructability meetings.

The procurement for CMAR is a public and competitive process. The engineer completes 30 percent drawings and specifications and publicly advertises for CMAR services. The CMAR RFP is based on a defined budget and includes a bid for lump sum preconstruction services, bid for lump sum general conditions cost, bid for percentage for overhead and profit, value engineering and constructability ideas, firm qualifications and reference projects, firm financials, and a proposed schedule to complete the work. Upon receipt of the proposals, the Town and engineer evaluate each submission for price, overall scope, firm experience, motivation, schedule, reference projects, and firm capability. The highest ranked proposal will be recommended for selection.

The project is awarded to the selected CMAR general contractor; however, the amount of the award is for the lump sum fee to assist the engineer and owner with value engineering and constructability decisions. This fee is generally a fraction of a percent of the total project cost. The initial process promotes team building between the owner, engineer, and contractor and provides investment from all parties. The goal of the value engineering phase of the project is to arrive at a GMP for a scope of work that incorporates the critical process items and project goals of the owner. It is an open book process, allowing the general contractor to provide real-time pricing for proposed additions, deletions, and revisions to the project scope *before* construction commences. Once the team is within the budget of the owner, the GMP is finalized, and the drawings and specifications are finalized based on the agreed upon scope.

There are multiple advantages to CMAR project delivery. The CMAR process encourages team building and partnering between the owner, engineer, and contractor. The general contractor provides input and is involved with the project cost and construction schedule. The process allows for value engineering early in the process, before construction has started, and provides an early guarantee of project cost. Collaboration during the design phase and contractor input can reduce the construction duration and incorporate constructability benefits. Generally, a contingency is agreed upon before construction commences and is included in the GMP. This eliminates change orders when unforeseen conditions arise or items are added to the project scope during construction. The biggest advantage is being able to deliver a project for a GMP according to the owner’s budget. There is always uncertainty in the construction phase and high prices have been observed using the design-build-build delivery method over the past couple years.

ANTICIPATED PROJECT SCHEDULE

Table 21 includes an anticipated project schedule. The construction schedule is dependent on which alternative the Town selects. Construction of the Cottonwood Creek surface water treatment alternative will take longer than constructing the IG treatment alternative.

Table 21 – Anticipated Project Schedule

Milestone	Completion Date
State Revolving Fund (SRF) Project Needs Assessment	October 2021
SRF Design and Engineering Grant Award	November 2021
Environmental Assessment	December 2021
CMAR Bid & Selection (if CMAR)	March 2022
CDPHE BDR Submission	June 2022
SRF Loan Application	June 2022
Department of Local Affairs (DOLA) Energy/Mineral Impact Assistance Fund (EIAF) Tier 2 Application	June 2022
CDPHE Approval	August 2022
DOLA EIAF Tier 2 Grant Award	September 2022
Notice to Proceed for Construction (if CMAR) or Bid (if D-B-B)	September 2022
Substantial Completion of Construction*	October 2023 or 2024

APPENDIX A – WATER QUALITY RESULTS

ANALYSIS FOR WATERBORNE PARTICULATES

Invoice 20210403

CH Diagnostic and Consulting Service, Inc.
512 5th Street, Berthoud, CO 80513
P: (970) 532-2078 F: (970) 532-3358

Customer 20211559
Town of Buena Vista
755 Gregg Drive
Buena Vista, CO 81211

Laboratory Information
Hand Delivery; 7/27/2021; 1240 Hrs; 12.8°C; Wound
Results submitted by:

Sample Identification:	Floc. 1, Direct Filtration WTP Floc Basin, Raw water		
Sample Information:	SOURCE: Stream or River; Unchlorinated		
Sample Date & Time:	7/26/2021 03:40 PM —» 7/26/2021 05:40 PM		**Sampler:** Wei Ye
Amount:	152.3463 L (40.25 gal)	**Filter Color:** Off white	**Filter Type:** Polypropylene wound cartridge
Date/Time Eluted:	7/27/2021 03:18 PM		**Centrifugate:** 0.0656 mL/100 L

RESULTS OF MICROSCOPIC PARTICULATE ANALYSIS

Amount of sample assayed: 0.7617 L

Amorphous Debris	clay (1-2 µm), silt (2-50 µm), sand (50-2000 µm), inorganic precipitate, detritus, aggregates
Algae	300,000/100 L, Euglena, Trachelomonas, predominantly Chlorophytes, Scenedesmus, Chlamydomonas, Ankistrodesmus, Pediastrum, Didymocystis, Sphaerocystis, Coelastrum, Cosmarium, Pandorina, Eudorina, Crucigenia, Nephrocytium, Stigeoclonium
Diatoms	2,000,000/100 L, predominantly Pennales, Achnanthes, Synedra, Cymbella, Nitzschia, Gomphonema, Navicula, Fragilaria, Didymosphenia, some Centrales, Cyclotella
Plant debris	ND
Rotifers	ND
Nematodes	ND
Pollen (pine)	2,000/100 L
Ameba	2,000/100 L, test
Ciliates	900/100 L
Colorless Flagellates	3,000/100 L
Crustaceans	ND
Other Arthropods	500/100 L, Arthropod pieces
Other	ND

This sample was analyzed for particulates following the procedure outlined in: Microscopic Particulate Analysis (MPA) for Filtration Plant Optimization. 1996. USEPA, Region 10, EPA 910-R-96-001. Particle free water used as wash water; organisms counted by natural unit count in a Palmer Maloney Counting Chamber; Section 11.1.1 omitted. All limitations stated in the method apply. If HV capsule or foam filter was received, method was modified by filtering sample through a Pall Envirochek™ HV capsule or IDEXX Filta-Max™ filter at the sample site. If *Giardia* and *Cryptosporidium* Analysis was also performed, then particulate extraction was modified.

ANALYSIS FOR WATERBORNE PARTICULATES

Invoice 20210403

CH Diagnostic and Consulting Service, Inc.
512 5th Street, Berthoud, CO 80513
P: (970) 532-2078 F: (970) 532-3358

Customer 20211559
Town of Buena Vista
755 Gregg Drive
Buena Vista, CO 81211

Laboratory Information
Hand Delivery; 7/27/2021; 1240 Hrs; 15.4°C; Wound
Results submitted by:

Sample Identification:	Grizzly 1, Cottonwood Creek @ WTP Intake, Raw water		
Sample Information:	SOURCE: Stream or River; Unchlorinated		
Sample Date & Time:	7/26/2021 01:00 PM —» 7/26/2021 03:00 PM		**Sampler:** unrec.
Amount:	162.1872 L (42.85 gal)	**Filter Color:** Light tan	**Filter Type:** Polypropylene wound cartridge
Date/Time Eluted:	7/27/2021 03:18 PM		**Centrifugate:** 0.308 mL/100 L

RESULTS OF MICROSCOPIC PARTICULATE ANALYSIS

Amount of sample assayed: 0.1622 L

Amorphous Debris	clay (1-2 µm), silt (2-50 µm), sand (50-2000 µm), inorganic precipitate, detritus, aggregates
Algae	80,000/100 L, predominantly Chlorophytes, Scenedesmus, Cosmarium, Pediastrum, Staurastrum, some Euglenophytes, Trachelomonas, Euglena, some Dinoflagellates, Peridinium
Diatoms	3,000,000/100 L, predominantly Pennales, Achnanthes, Synedra, Navicula, Cymbella, Diatoma, Cocconeis, Nitzschia, Didymosphenia, some Centrales, Cyclotella
Plant debris	ND
Rotifers	600/100 L
Nematodes	ND
Pollen (pine)	9,000/100 L
Ameba	10,000/100 L
Ciliates	1,000/100 L
Colorless Flagellates	9,000/100 L
Crustaceans	ND
Other Arthropods	ND
Other	ND

This sample was analyzed for particulates following the procedure outlined in: Microscopic Particulate Analysis (MPA) for Filtration Plant Optimization. 1996. USEPA, Region 10, EPA 910-R-96-001. Particle free water used as wash water; organisms counted by natural unit count in a Palmer Maloney Counting Chamber; Section 11.1.1 omitted. All limitations stated in the method apply. If HV capsule or foam filter was received, method was modified by filtering sample through a Pall Envirochek™ HV capsule or IDEXX Filta-Max™ filter at the sample site. If *Giardia* and *Cryptosporidium* Analysis was also performed, then particulate extraction was modified.

HAZEN
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Fax: (303) 278-1528

Lab Control ID: 21M02209
Received: Jun 16, 2021
Reported: Jul 08, 2021
Purchase Order No.
None Received

Customer ID: 04683Z
Account ID: Z05752

Ryan Wienpahl
JVA, Inc.
1319 Spruce St
Boulder, CO 80301

ANALYTICAL REPORT

Report may only be copied in its entirety.
Results reported herein relate only to discrete samples submitted by the client. Hazen Research, Inc. does not warrant that the results are representative of anything other than the samples that were received in the laboratory

By:______________________________
Jessica Axen
Analytical Laboratories Director

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ANALYTICAL REPORT

Ryan Wienpahl
JVA, Inc.

X-Ray Diffraction (XRD) Analysis

Two samples, shown in Table 1, were analyzed to identify and quantify the mineral constituents.

Table 1. Samples Analyzed

Number	Hazen ID
1	21M02209-1
2	21M02209-2

The samples were ground in a mortar and pestle and scanned on a zero-background plate[1].

Please note the detection limit of XRD analysis for certain constituents can be as high as 2 to 5 %. High background and humps in the XRD patterns between 20° and 40° 2-theta indicate the samples contain an amorphous component. Data given in Table 2 are for crystalline components only.

A summary of the results is shown in Table 2 and the diffraction patterns are presented in Figures 1-2.

[1] Analysis performed using a Bruker D8 Advance XRD with Davinci design and a Lynxeye detector utilizing cobalt radiation produced at 35 kV and 40 mA. The scan range is 5°-85° 2theta, with a step of 0.02° 2theta and a time per step of 0.4 s. Mineral amounts calculated by the peak relative intensity and area method (RIR).

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Table 2. XRD Results

Sample ID	Mineral Constituents*			
	Major (>20 wt%)	Subordinate (10 to 20 wt%)	Minor (5 to 10 wt%)	Trace (<5 wt%)
21M02209-1	Halite, Bassanite	Quartz	nd	Laumontite
21M02209-2	Quartz	Calcite, Muscovite	Halite	nd

nd = none detected

*Crystalline constituents only

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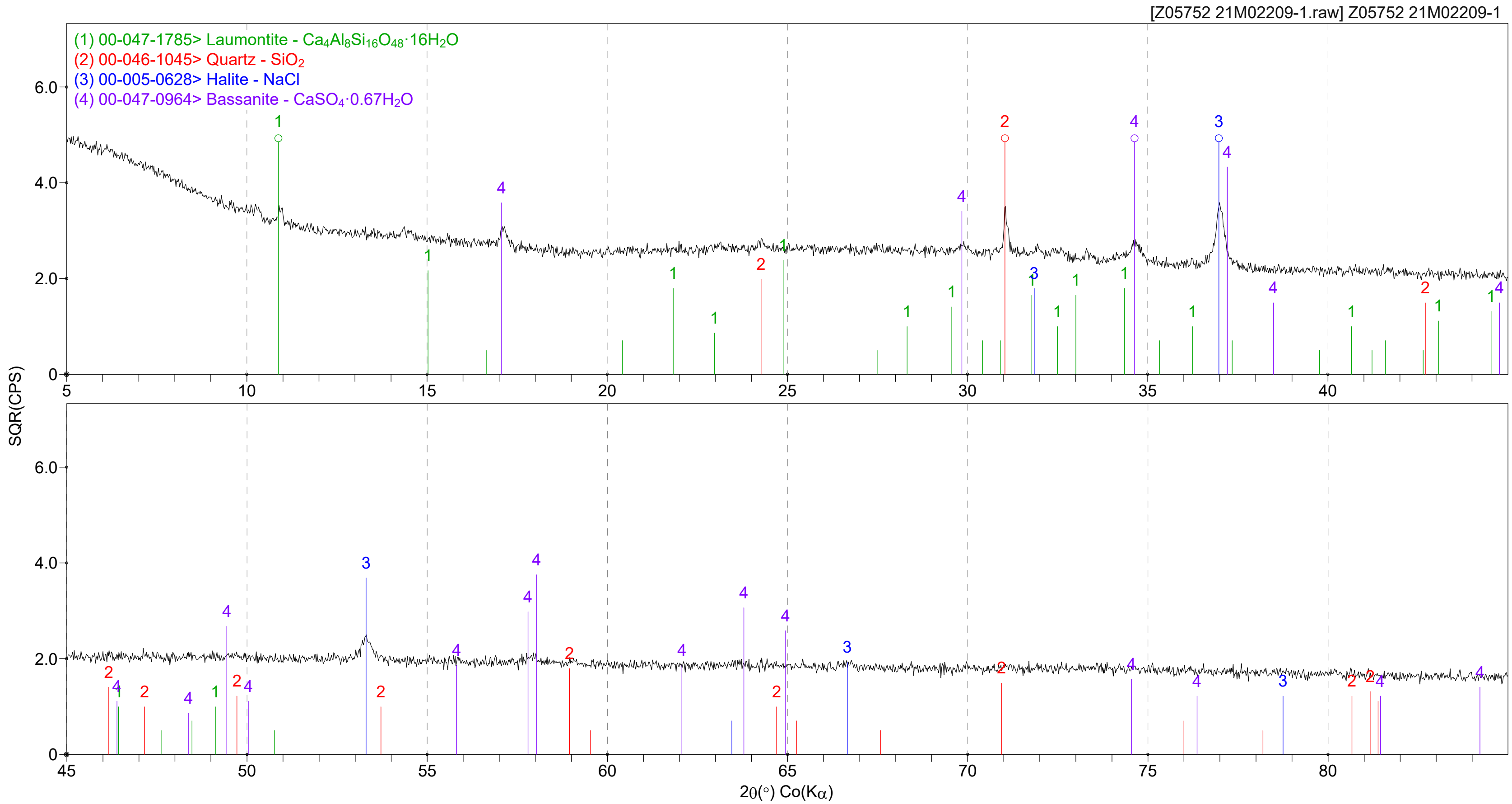

Figure 1. XRD Pattern of Sample 21M02209-1

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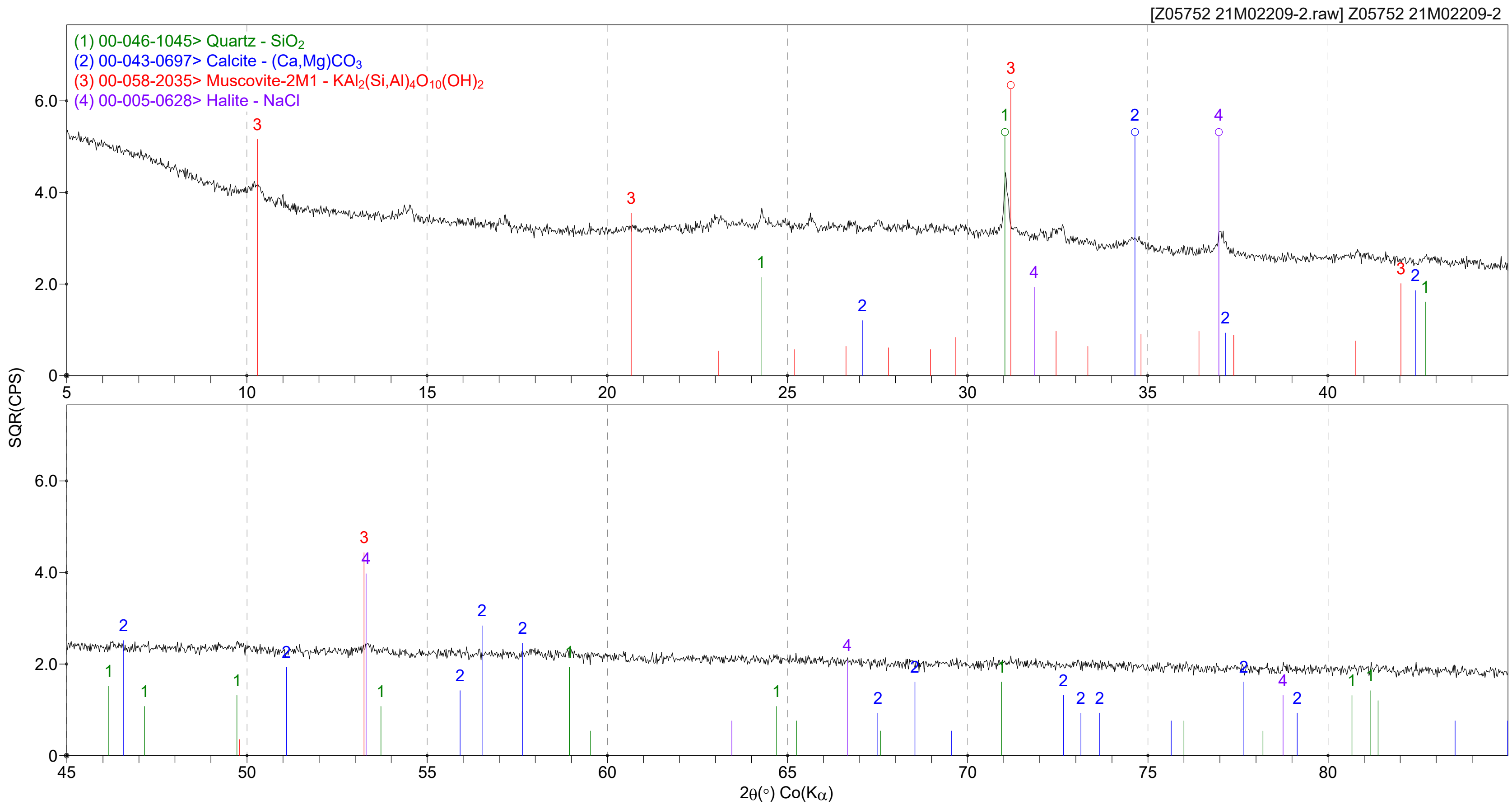


Figure 2. XRD Pattern of Sample 21M02209-2

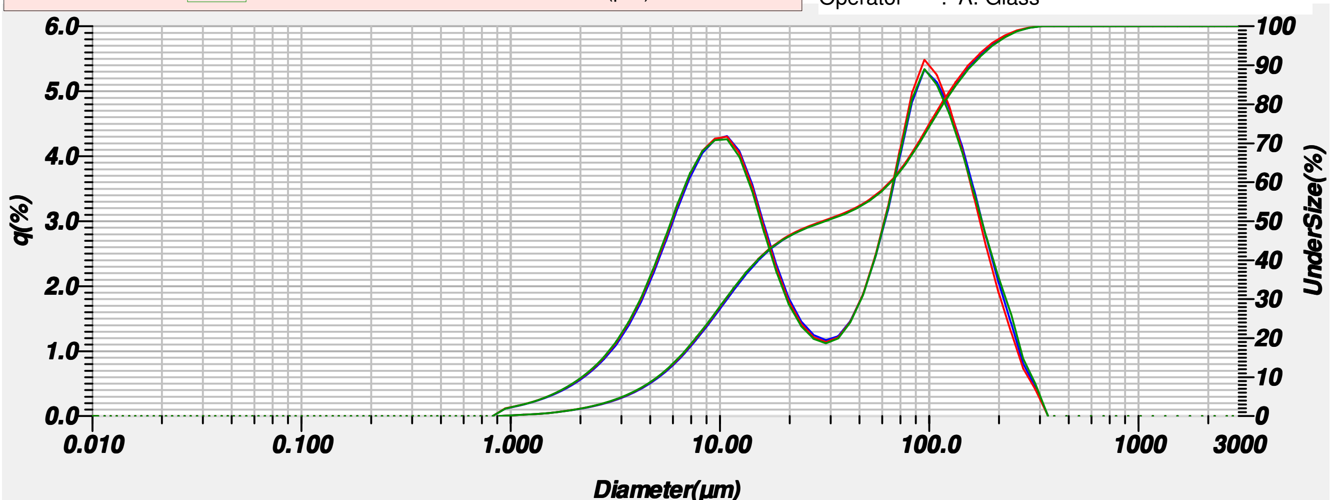
Horiba Particle Size Distribution Analyzer LA-950 V2

Project Number	:	Z05752
Sample Name	:	Z05752 21M02209-1
ID#	:	202106171429958
Transmittance(R)	:	84.0(%)
Transmittance(B)	:	71.2(%)
Circulation Speed	:	7
Agitation Speed	:	5
Ultra Sonic	:	OFF
Distribution Base	:	Volume
Material	:	Pre-Sed Basin Filter 1
Source	:	
Test or Assay. Number	:	21M02209-1
Refractive Index (R)	:	1.55-0.50i(1.33)[1.55-0.50(1.550 - 0.500i),1.33(1.333)]
Refractive Index (B)	:	1.55-0.50i(1.33)[1.55-0.50(1.550 - 0.500i),1.33(1.333)]

Median Size	:	31.50181(µm)
Mean Size	:	62.53477(µm)
R Parameter	:	3.0983E-2
Chi Square	:	0.003623
Diameter on Cumulative %	:	(1)5.000 (%)- 3.5163(µm)
	:	(2)10.00 (%)- 5.1223(µm)
	:	(3)20.00 (%)- 7.8118(µm)
	:	(4)30.00 (%)- 10.8039(µm)
	:	(5)40.00 (%)- 15.3128(µm)
	:	(6)60.00 (%)- 65.0780(µm)
	:	(7)70.00 (%)- 89.3121(µm)
	:	(8)80.00 (%)- 115.7792(µm)
	:	(9)90.00 (%)- 158.1897(µm)
	:	(10)95.00 (%)- 197.2762(µm)

Data Name	Graph Type	Sample Name	Median Size
202106171429958		Z05752 21M02209-1	31.50181(µm)
202106171430959		Z05752 21M02209-1	30.95081(µm)
202106171430960		Z05752 21M02209-1	31.97252(µm)

Remarks 1	:	
Project #	:	Z05752 04683Z
Preparation	:	
Operator	:	A. Glass



No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)
1	0.011	0.000	0.000	25	0.296	0.000	0.000	49	7.697	3.681	19.558	73	200.000	2.746	95.277
2	0.013	0.000	0.000	26	0.339	0.000	0.000	50	8.816	4.045	23.603	74	229.075	2.044	97.322
3	0.015	0.000	0.000	27	0.389	0.000	0.000	51	10.097	4.251	27.854	75	262.376	1.437	98.758
4	0.017	0.000	0.000	28	0.445	0.000	0.000	52	11.565	4.305	32.159	76	300.518	0.798	99.557
5	0.020	0.000	0.000	29	0.510	0.000	0.000	53	13.246	4.069	36.228	77	344.206	0.443	100.000
6	0.022	0.000	0.000	30	0.584	0.000	0.000	54	15.172	3.572	39.800	78	394.244	0.000	100.000
7	0.026	0.000	0.000	31	0.669	0.000	0.000	55	17.377	2.937	42.737	79	451.556	0.000	100.000
8	0.029	0.000	0.000	32	0.766	0.000	0.000	56	19.904	2.313	45.051	80	517.200	0.000	100.000
9	0.034	0.000	0.000	33	0.877	0.000	0.000	57	22.797	1.806	46.856	81	592.387	0.000	100.000
10	0.039	0.000	0.000	34	1.005	0.112	0.112	58	26.111	1.452	48.308	82	678.504	0.000	100.000
11	0.044	0.000	0.000	35	1.151	0.152	0.264	59	29.907	1.245	49.554	83	777.141	0.000	100.000
12	0.051	0.000	0.000	36	1.318	0.198	0.462	60	34.255	1.166	50.720	84	890.116	0.000	100.000
13	0.058	0.000	0.000	37	1.510	0.257	0.719	61	39.234	1.226	51.946	85	1019.515	0.000	100.000
14	0.067	0.000	0.000	38	1.729	0.334	1.053	62	44.938	1.469	53.416	86	1167.725	0.000	100.000
15	0.076	0.000	0.000	39	1.981	0.429	1.482	63	51.471	1.865	55.280	87	1337.481	0.000	100.000
16	0.087	0.000	0.000	40	2.269	0.545	2.026	64	58.953	2.431	57.711	88	1531.914	0.000	100.000
17	0.100	0.000	0.000	41	2.599	0.689	2.715	65	67.523	3.143	60.854	89	1754.613	0.000	100.000
18	0.115	0.000	0.000	42	2.976	0.870	3.585	66	77.339	3.984	64.838	90	2009.687	0.000	100.000
19	0.131	0.000	0.000	43	3.409	1.098	4.683	67	88.583	4.840	69.678	91	2301.841	0.000	100.000
20	0.150	0.000	0.000	44	3.905	1.387	6.071	68	101.460	5.327	75.005	92	2636.467	0.000	100.000
21	0.172	0.000	0.000	45	4.472	1.747	7.818	69	116.210	5.135	80.140	93	3000.000	0.000	100.000
22	0.197	0.000	0.000	46	5.122	2.182	10.000	70	133.103	4.740	84.880				
23	0.226	0.000	0.000	47	5.867	2.678	12.677	71	152.453	4.173	89.054				
24	0.259	0.000	0.000	48	6.720	3.199	15.876	72	174.616	3.478	92.531				

Hazen Research Inc.

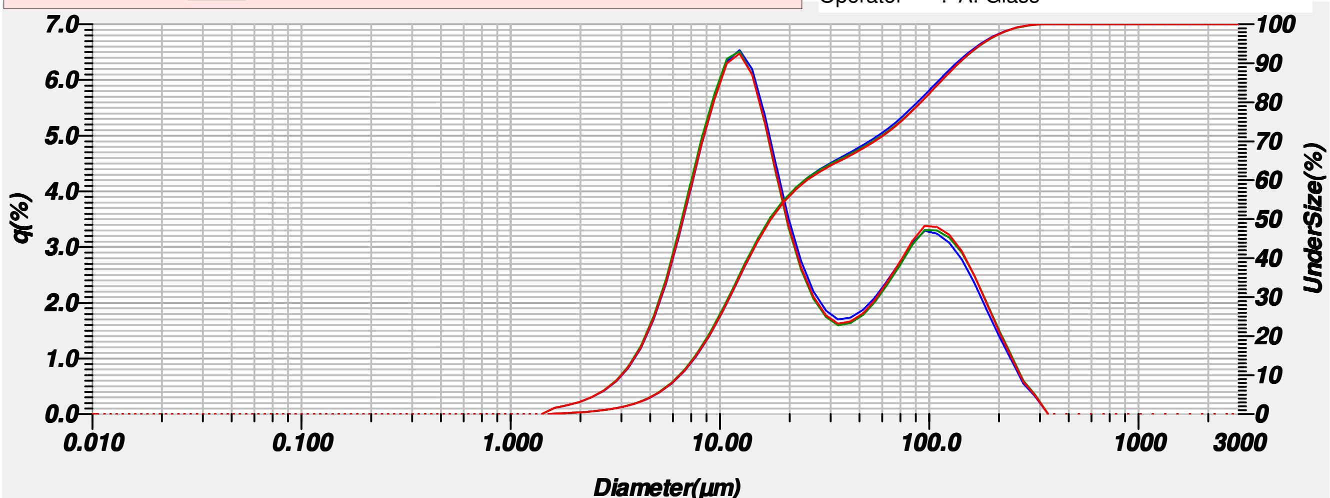
Horiba Particle Size Distribution Analyzer LA-950 V2

Median Size : 17.44306(µm)
Mean Size : 47.56733(µm)
R Parameter : 3.2049E-2
Chi Square : 0.004825
Diameter on Cumulative % : (1)5.000 (%)- 4.9397(µm)
: (2)10.00 (%)- 6.4719(µm)
: (3)20.00 (%)- 8.8703(µm)
: (4)30.00 (%)- 11.1402(µm)
: (5)40.00 (%)- 13.7564(µm)
: (6)60.00 (%)- 25.4393(µm)
: (7)70.00 (%)- 51.9327(µm)
: (8)80.00 (%)- 88.0141(µm)
: (9)90.00 (%)- 134.8280(µm)
: (10)95.00 (%)- 176.2177(µm)

Project Number : Z05752
Sample Name : Z05752 21M02209-2
ID# : 202106170940934
Transmittance(R) : 81.1(%)
Transmittance(B) : 71.3(%)
Circulation Speed : 7
Agitation Speed : 5
Ultra Sonic : OFF
Distribution Base : Volume
Material : Pre-Sed Basin Filter 2
Source :
Test or Assay. Number : 21M02209-2
Refractive Index (R) : 1.55-0.50i(1.33)[1.55-0.50(1.550 - 0.500i),1.33(1.333)]
Refractive Index (B) : 1.55-0.50i(1.33)[1.55-0.50(1.550 - 0.500i),1.33(1.333)]

Data Name	Graph Type	Sample Name	Median Size
202106170940934		Z05752 21M02209-2	17.44306(µm)
202106170940935		Z05752 21M02209-2	17.54548(µm)
202106170941936		Z05752 21M02209-2	17.22934(µm)

Remarks 1 :
Project # : Z05752 04683Z
Preparation :
Operator : A. Glass



No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)
1	0.011	0.000	0.000	25	0.296	0.000	0.000	49	7.697	3.997	14.856	73	200.000	1.886	96.759
2	0.013	0.000	0.000	26	0.339	0.000	0.000	50	8.816	4.885	19.741	74	229.075	1.409	98.168
3	0.015	0.000	0.000	27	0.389	0.000	0.000	51	10.097	5.674	25.415	75	262.376	0.983	99.151
4	0.017	0.000	0.000	28	0.445	0.000	0.000	52	11.565	6.329	31.745	76	300.518	0.546	99.697
5	0.020	0.000	0.000	29	0.510	0.000	0.000	53	13.246	6.531	38.276	77	344.206	0.303	100.000
6	0.022	0.000	0.000	30	0.584	0.000	0.000	54	15.172	6.191	44.467	78	394.244	0.000	100.000
7	0.026	0.000	0.000	31	0.669	0.000	0.000	55	17.377	5.410	49.877	79	451.556	0.000	100.000
8	0.029	0.000	0.000	32	0.766	0.000	0.000	56	19.904	4.427	54.304	80	517.200	0.000	100.000
9	0.034	0.000	0.000	33	0.877	0.000	0.000	57	22.797	3.488	57.792	81	592.387	0.000	100.000
10	0.039	0.000	0.000	34	1.005	0.000	0.000	58	26.111	2.733	60.525	82	678.504	0.000	100.000
11	0.044	0.000	0.000	35	1.151	0.000	0.000	59	29.907	2.197	62.722	83	777.141	0.000	100.000
12	0.051	0.000	0.000	36	1.318	0.000	0.000	60	34.255	1.855	64.577	84	890.116	0.000	100.000
13	0.058	0.000	0.000	37	1.510	0.000	0.000	61	39.234	1.695	66.272	85	1019.515	0.000	100.000
14	0.067	0.000	0.000	38	1.729	0.109	0.109	62	44.938	1.726	67.998	86	1167.725	0.000	100.000
15	0.076	0.000	0.000	39	1.981	0.151	0.260	63	51.471	1.864	69.862	87	1337.481	0.000	100.000
16	0.087	0.000	0.000	40	2.269	0.210	0.470	64	58.953	2.097	71.959	88	1531.914	0.000	100.000
17	0.100	0.000	0.000	41	2.599	0.293	0.764	65	67.523	2.403	74.363	89	1754.613	0.000	100.000
18	0.115	0.000	0.000	42	2.976	0.413	1.177	66	77.339	2.722	77.084	90	2009.687	0.000	100.000
19	0.131	0.000	0.000	43	3.409	0.585	1.762	67	88.583	3.061	80.145	91	2301.841	0.000	100.000
20	0.150	0.000	0.000	44	3.905	0.832	2.594	68	101.460	3.284	83.430	92	2636.467	0.000	100.000
21	0.172	0.000	0.000	45	4.472	1.184	3.777	69	116.210	3.235	86.664	93	3000.000	0.000	100.000
22	0.197	0.000	0.000	46	5.122	1.669	5.446	70	133.103	3.073	89.737				
23	0.226	0.000	0.000	47	5.867	2.310	7.756	71	152.453	2.776	92.513				
24	0.259	0.000	0.000	48	6.720	3.103	10.859	72	174.616	2.360	94.873				

Hazen Research Inc.

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Lab Control ID: 21M02222
Received: Jun 17, 2021
Reported: Jul 08, 2021
Purchase Order No.
Buena Vista Pilot 01

Customer ID: 04683Z
Account ID: Z05752

Ryan Wienpahl
JVA, Inc.
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Boulder, CO 80301

ANALYTICAL REPORT

Report may only be copied in its entirety.
Results reported herein relate only to discrete samples submitted by the client. Hazen Research, Inc. does not warrant that the results are representative of anything other than the samples that were received in the laboratory

By:______________________________

Jessica Axen
Analytical Laboratories Director

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Buena Vista Pilot 01

Customer ID: 04683Z
Account ID: Z05752

ANALYTICAL REPORT

Ryan Wienpahl
JVA, Inc.

X-Ray Diffraction (XRD) Analysis

Three samples, shown in Table 1, were analyzed to identify and quantify the mineral constituents.

Table 1. Samples Analyzed

Number	Hazen ID
1	21M02222-1
2	21M02222-2
3	21M02222-3

The samples were ground in a mortar and pestle and scanned on a zero-background plate[1].

Please note the detection limit of XRD analysis for certain constituents can be as high as 2 to 5 %. High background and humps in the XRD patterns between 20° and 40° 2-theta indicate the samples contain an amorphous component. Data given in Table 2 are for crystalline components only.

A summary of the results is shown in Table 2 and the diffraction patterns are presented in Figures 1-3.

[1] Analysis performed using a Bruker D8 Advance XRD with Davinci design and a Lynxeye detector utilizing cobalt radiation produced at 35 kV and 40 mA. The scan range is 5°-85° 2theta, with a step of 0.02° 2theta and a time per step of 0.4 s. Mineral amounts calculated by the peak relative intensity and area method (RIR).

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Table 2. XRD Results

Sample ID	Mineral Constituents*			
	Major (>20 wt%)	Subordinate (10 to 20 wt%)	Minor (5 to 10 wt%)	Trace (<5 wt%)
21M02222-1	Albite Clinochlore	Quartz, Microcline, Muscovite	Laumontite	Tremolite
21M02222-2	Albite, Muscovite	Quartz, Microcline, Clinochlore	Laumontite	Tremolite
21M02222-3	Albite, Muscovite	Quartz, Microcline	Clinochlore, Tremolite	Laumontite

nd = none detected

*Crystalline constituents only

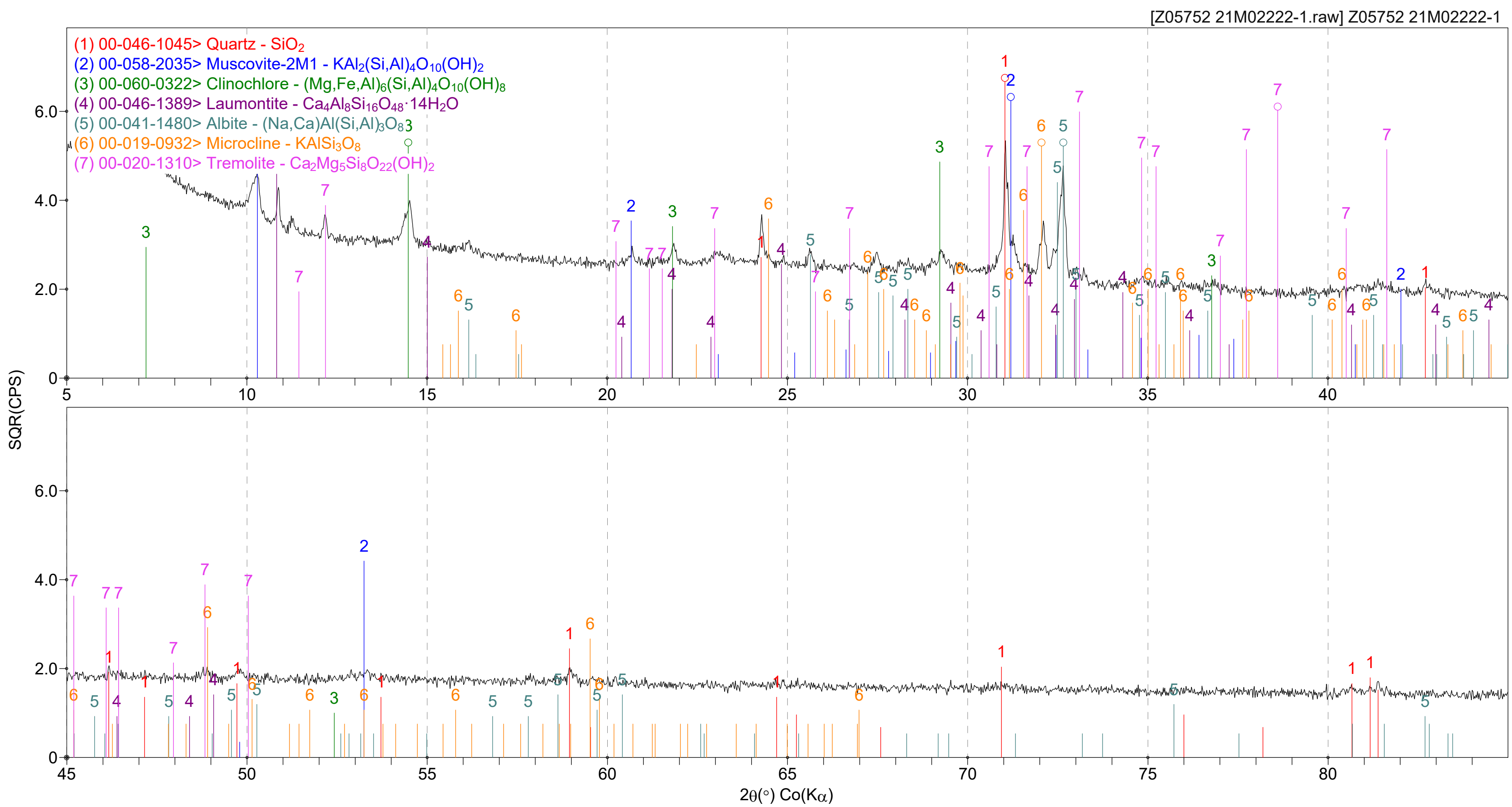

Figure 1. XRD Pattern of Sample 21M02222-1

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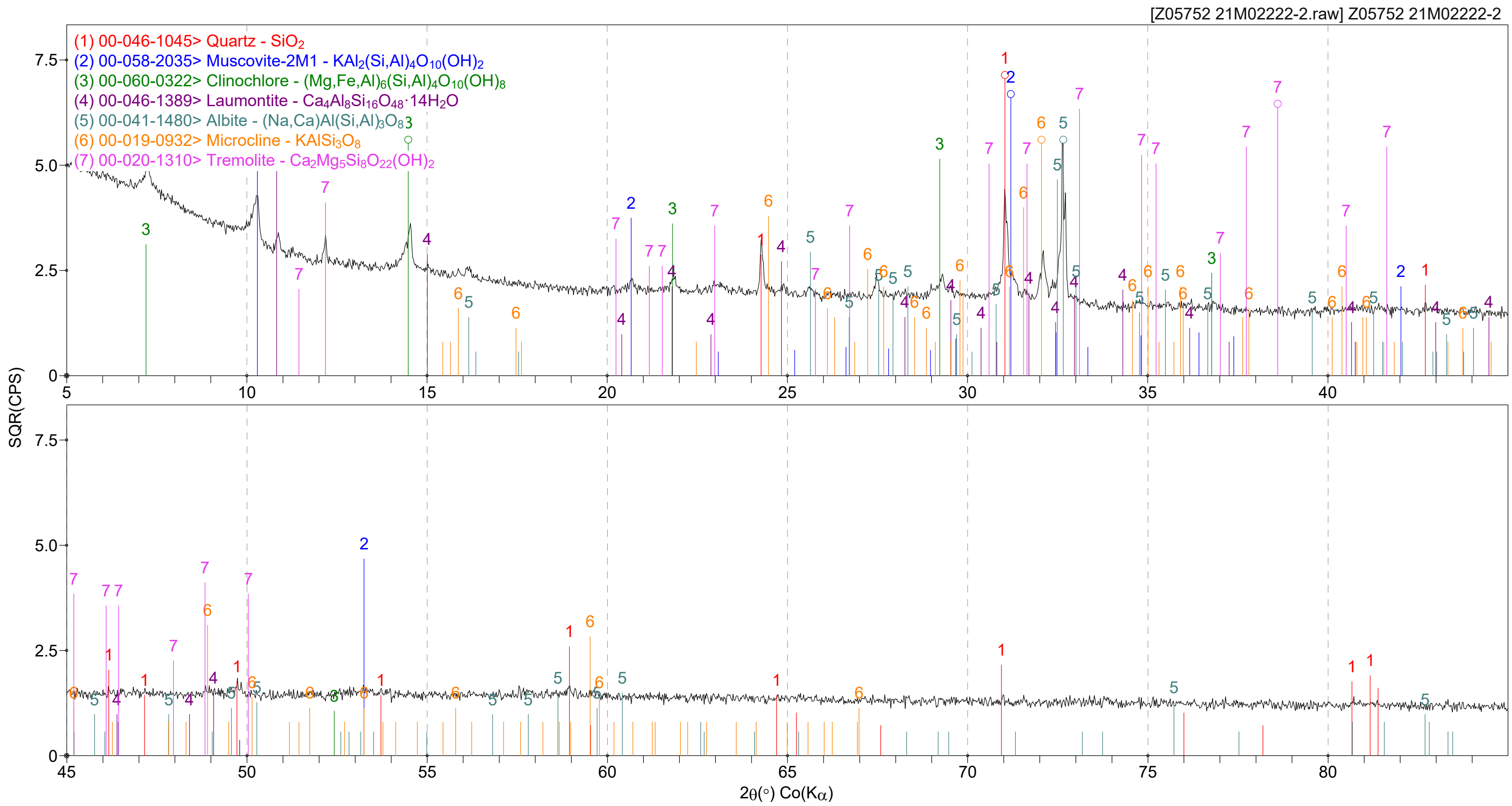

Figure 2. XRD Pattern of Sample 21M02222-2

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Fax: (303) 278-1528

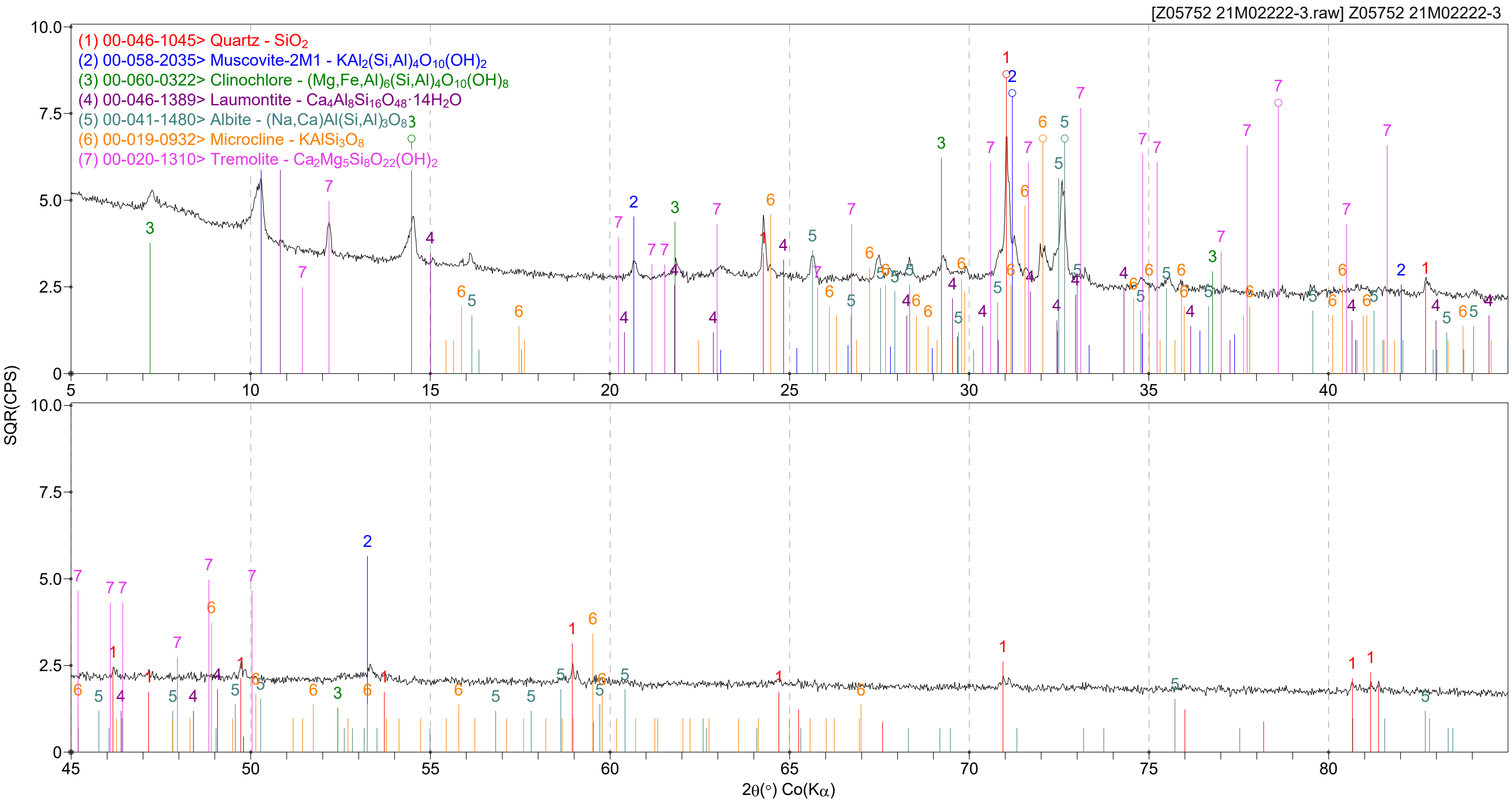


Figure 3. XRD Pattern of Sample 21M02222-3

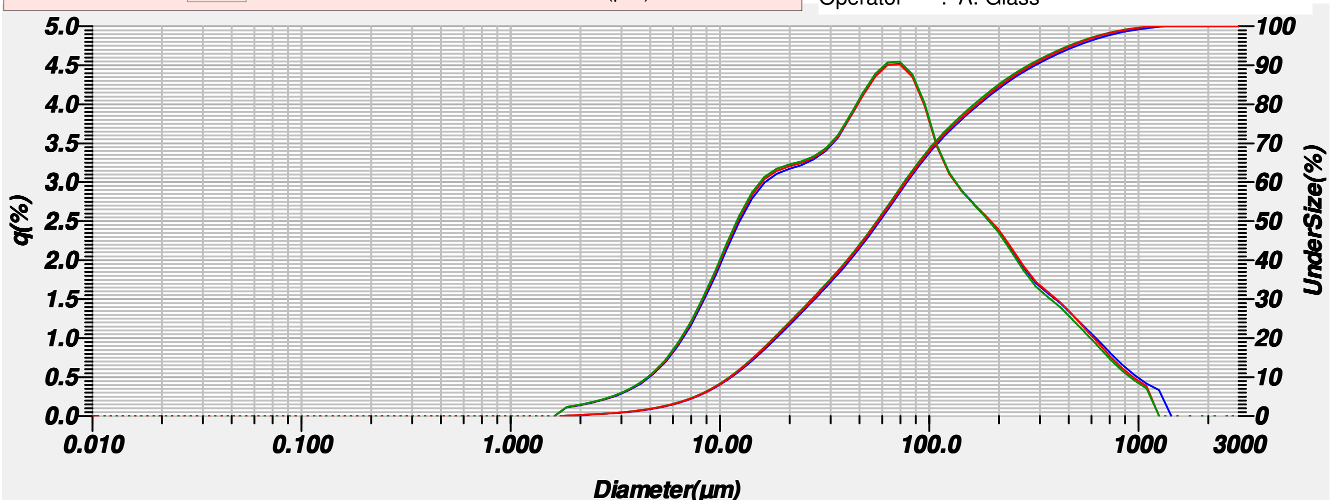
Horiba Particle Size Distribution Analyzer LA-950 V2

Median Size	:	57.87016(µm)
Mean Size	:	124.60463(µm)
R Parameter	:	1.8485E-2
Chi Square	:	0.000335
Diameter on Cumulative %	:	(1)5.000 (%)- 7.7762(µm)
	:	(2)10.00 (%)- 11.3705(µm)
	:	(3)20.00 (%)- 18.5206(µm)
	:	(4)30.00 (%)- 28.3231(µm)
	:	(5)40.00 (%)- 41.6817(µm)
	:	(6)60.00 (%)- 78.2767(µm)
	:	(7)70.00 (%)- 109.9084(µm)
	:	(8)80.00 (%)- 173.4413(µm)
	:	(9)90.00 (%)- 322.1306(µm)
	:	(10)95.00 (%)- 509.4927(µm)

Project Number	:	Z05752
Sample Name	:	Z05752 21M02222-1
ID#	:	202106210837009
Transmittance(R)	:	73.6(%)
Transmittance(B)	:	72.8(%)
Circulation Speed	:	7
Agitation Speed	:	5
Ultra Sonic	:	OFF
Distribution Base	:	Volume
Material	:	Cottonwood Creek Pre-Filter 1
Source	:	
Test or Assay. Number	:	21M02222-1
Refractive Index (R)	:	1.55-0.50i(1.33)[1.55-0.50(1.550 - 0.500i),1.33(1.333)]
Refractive Index (B)	:	1.55-0.50i(1.33)[1.55-0.50(1.550 - 0.500i),1.33(1.333)]

Data Name	Graph Type	Sample Name	Median Size
202106210837009		Z05752 21M02222-1	57.87016(µm)
202106210838010		Z05752 21M02222-1	56.94280(µm)
202106210838011		Z05752 21M02222-1	56.13605(µm)

Remarks 1	:	
Project #	:	Z05752 04683Z
Preparation	:	
Operator	:	A. Glass



No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)
1	0.011	0.000	0.000	25	0.296	0.000	0.000	49	7.697	1.150	4.890	73	200.000	2.557	82.692
2	0.013	0.000	0.000	26	0.339	0.000	0.000	50	8.816	1.448	6.338	74	229.075	2.377	85.068
3	0.015	0.000	0.000	27	0.389	0.000	0.000	51	10.097	1.783	8.121	75	262.376	2.151	87.219
4	0.017	0.000	0.000	28	0.445	0.000	0.000	52	11.565	2.147	10.268	76	300.518	1.907	89.126
5	0.020	0.000	0.000	29	0.510	0.000	0.000	53	13.246	2.498	12.766	77	344.206	1.708	90.834
6	0.022	0.000	0.000	30	0.584	0.000	0.000	54	15.172	2.788	15.554	78	394.244	1.571	92.405
7	0.026	0.000	0.000	31	0.669	0.000	0.000	55	17.377	2.989	18.543	79	451.556	1.446	93.851
8	0.029	0.000	0.000	32	0.766	0.000	0.000	56	19.904	3.104	21.647	80	517.200	1.292	95.143
9	0.034	0.000	0.000	33	0.877	0.000	0.000	57	22.797	3.166	24.813	81	592.387	1.138	96.281
10	0.039	0.000	0.000	34	1.005	0.000	0.000	58	26.111	3.217	28.030	82	678.504	0.981	97.262
11	0.044	0.000	0.000	35	1.151	0.000	0.000	59	29.907	3.288	31.318	83	777.141	0.813	98.074
12	0.051	0.000	0.000	36	1.318	0.000	0.000	60	34.255	3.398	34.716	84	890.116	0.659	98.733
13	0.058	0.000	0.000	37	1.510	0.000	0.000	61	39.234	3.573	38.289	85	1019.515	0.523	99.256
14	0.067	0.000	0.000	38	1.729	0.000	0.000	62	44.938	3.838	42.127	86	1167.725	0.414	99.670
15	0.076	0.000	0.000	39	1.981	0.110	0.110	63	51.471	4.114	46.241	87	1337.481	0.330	100.000
16	0.087	0.000	0.000	40	2.269	0.136	0.245	64	58.953	4.354	50.595	88	1531.914	0.000	100.000
17	0.100	0.000	0.000	41	2.599	0.167	0.412	65	67.523	4.503	55.098	89	1754.613	0.000	100.000
18	0.115	0.000	0.000	42	2.976	0.206	0.619	66	77.339	4.515	59.613	90	2009.687	0.000	100.000
19	0.131	0.000	0.000	43	3.409	0.257	0.876	67	88.583	4.358	63.971	91	2301.841	0.000	100.000
20	0.150	0.000	0.000	44	3.905	0.325	1.201	68	101.460	3.990	67.961	92	2636.467	0.000	100.000
21	0.172	0.000	0.000	45	4.472	0.414	1.615	69	116.210	3.460	71.421	93	3000.000	0.000	100.000
22	0.197	0.000	0.000	46	5.122	0.535	2.150	70	133.103	3.111	74.532				
23	0.226	0.000	0.000	47	5.867	0.693	2.843	71	152.453	2.889	77.421				
24	0.259	0.000	0.000	48	6.720	0.897	3.740	72	174.616	2.713	80.135				

Hazen Research Inc.

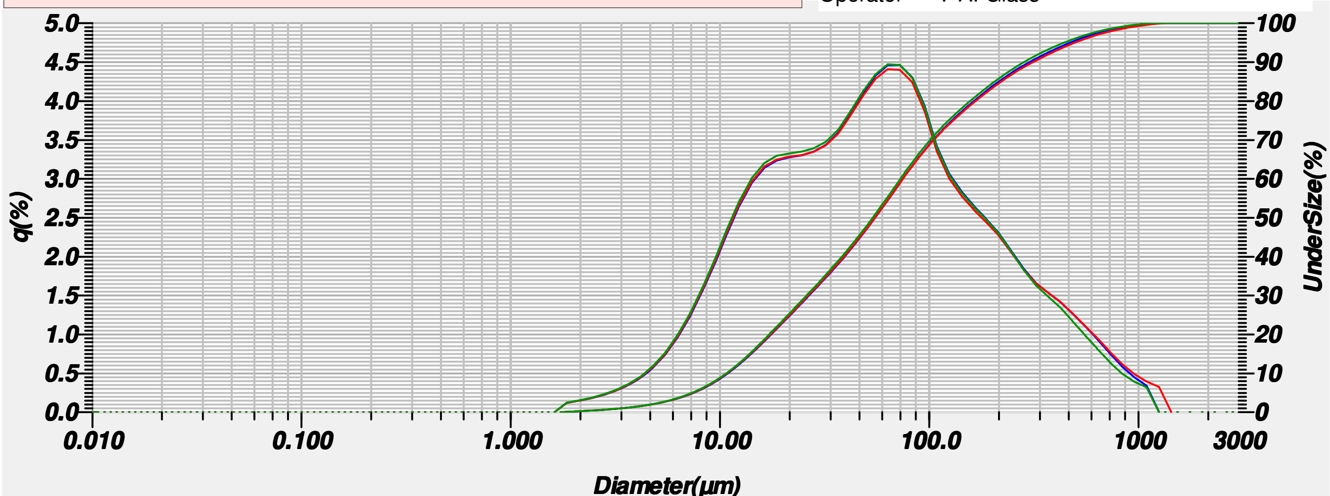
Horiba Particle Size Distribution Analyzer LA-950 V2

Project Number	:	Z05752
Sample Name	:	Z05752 21M02222-2
ID#	:	202106211059030
Transmittance(R)	:	71.7(%)
Transmittance(B)	:	70.4(%)
Circulation Speed	:	6
Agitation Speed	:	5
Ultra Sonic	:	OFF
Distribution Base	:	Volume
Material	:	Cottonwood Creek LT2 Filter 1
Source	:	
Test or Assay. Number	:	21M02222-2
Refractive Index (R)	:	1.55-0.50i(1.33)[1.55-0.50(1.550 - 0.500i),1.33(1.333)]
Refractive Index (B)	:	1.55-0.50i(1.33)[1.55-0.50(1.550 - 0.500i),1.33(1.333)]

Median Size	:	55.09502(µm)
Mean Size	:	115.93135(µm)
R Parameter	:	2.1989E-2
Chi Square	:	0.000512
Diameter on Cumulative %	:	(1)5.000 (%)- 7.4899(µm)
	:	(2)10.00 (%)- 10.8993(µm)
	:	(3)20.00 (%)- 17.5700(µm)
	:	(4)30.00 (%)- 26.6062(µm)
	:	(5)40.00 (%)- 39.3676(µm)
	:	(6)60.00 (%)- 74.8600(µm)
	:	(7)70.00 (%)- 104.2962(µm)
	:	(8)80.00 (%)- 163.7264(µm)
	:	(9)90.00 (%)- 301.5690(µm)
	:	(10)95.00 (%)- 472.8401(µm)

Data Name	Graph Type	Sample Name	Median Size
202106211059030		Z05752 21M02222-2	55.09502(µm)
202106211059031		Z05752 21M02222-2	54.88581(µm)
202106211100032		Z05752 21M02222-2	53.61482(µm)

Remarks 1	:	
Project #	:	Z05752 04683Z
Preparation	:	
Operator	:	A. Glass



No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)
1	0.011	0.000	0.000	25	0.296	0.000	0.000	49	7.697	1.236	5.248	73	200.000	2.479	83.733
2	0.013	0.000	0.000	26	0.339	0.000	0.000	50	8.816	1.553	6.801	74	229.075	2.297	86.031
3	0.015	0.000	0.000	27	0.389	0.000	0.000	51	10.097	1.908	8.709	75	262.376	2.079	88.109
4	0.017	0.000	0.000	28	0.445	0.000	0.000	52	11.565	2.292	11.001	76	300.518	1.848	89.957
5	0.020	0.000	0.000	29	0.510	0.000	0.000	53	13.246	2.654	13.655	77	344.206	1.661	91.619
6	0.022	0.000	0.000	30	0.584	0.000	0.000	54	15.172	2.946	16.601	78	394.244	1.535	93.153
7	0.026	0.000	0.000	31	0.669	0.000	0.000	55	17.377	3.137	19.738	79	451.556	1.417	94.571
8	0.029	0.000	0.000	32	0.766	0.000	0.000	56	19.904	3.233	22.970	80	517.200	1.265	95.836
9	0.034	0.000	0.000	33	0.877	0.000	0.000	57	22.797	3.271	26.241	81	592.387	1.105	96.941
10	0.039	0.000	0.000	34	1.005	0.000	0.000	58	26.111	3.296	29.537	82	678.504	0.937	97.878
11	0.044	0.000	0.000	35	1.151	0.000	0.000	59	29.907	3.345	32.882	83	777.141	0.753	98.631
12	0.051	0.000	0.000	36	1.318	0.000	0.000	60	34.255	3.434	36.315	84	890.116	0.586	99.217
13	0.058	0.000	0.000	37	1.510	0.000	0.000	61	39.234	3.589	39.904	85	1019.515	0.445	99.662
14	0.067	0.000	0.000	38	1.729	0.000	0.000	62	44.938	3.836	43.740	86	1167.725	0.338	100.000
15	0.076	0.000	0.000	39	1.981	0.116	0.116	63	51.471	4.094	47.835	87	1337.481	0.000	100.000
16	0.087	0.000	0.000	40	2.269	0.144	0.260	64	58.953	4.319	52.154	88	1531.914	0.000	100.000
17	0.100	0.000	0.000	41	2.599	0.178	0.439	65	67.523	4.457	56.611	89	1754.613	0.000	100.000
18	0.115	0.000	0.000	42	2.976	0.221	0.659	66	77.339	4.460	61.071	90	2009.687	0.000	100.000
19	0.131	0.000	0.000	43	3.409	0.275	0.935	67	88.583	4.300	65.371	91	2301.841	0.000	100.000
20	0.150	0.000	0.000	44	3.905	0.348	1.282	68	101.460	3.936	69.307	92	2636.467	0.000	100.000
21	0.172	0.000	0.000	45	4.472	0.445	1.727	69	116.210	3.411	72.718	93	3000.000	0.000	100.000
22	0.197	0.000	0.000	46	5.122	0.574	2.302	70	133.103	3.061	75.779				
23	0.226	0.000	0.000	47	5.867	0.745	3.047	71	152.453	2.831	78.610				
24	0.259	0.000	0.000	48	6.720	0.965	4.012	72	174.616	2.644	81.254				

Hazen Research Inc.

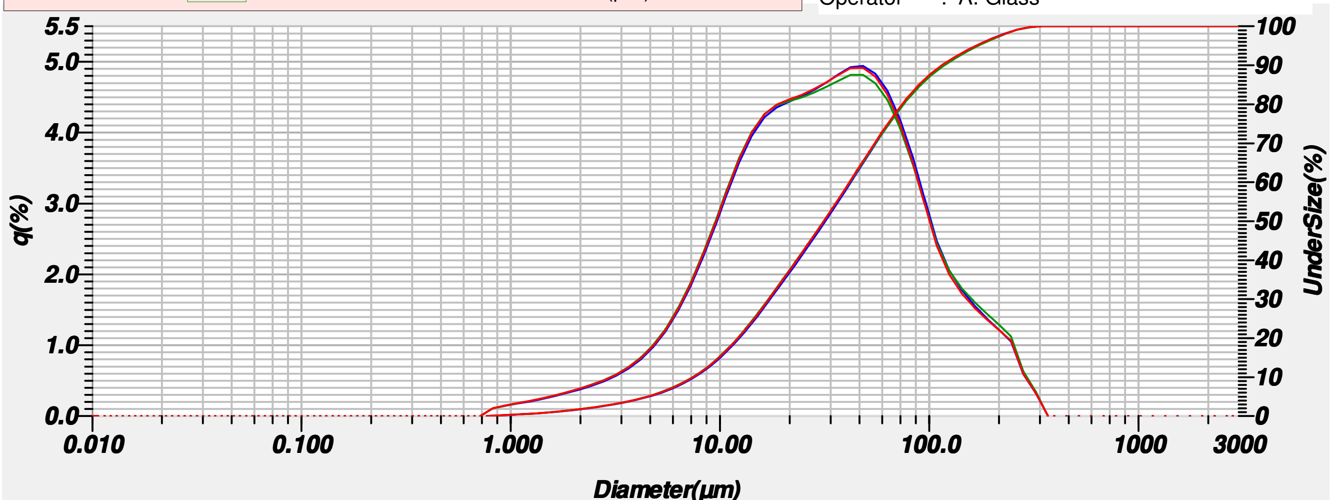
Horiba Particle Size Distribution Analyzer LA-950 V2

Project Number	:	Z05752
Sample Name	:	Z05752 21M02222-3
ID#	:	202106220935045
Transmittance(R)	:	75.8(%)
Transmittance(B)	:	70.0(%)
Circulation Speed	:	6
Agitation Speed	:	5
Ultra Sonic	:	OFF
Distribution Base	:	Volume
Material	:	Infiltration Gallery Filter 1
Source	:	
Test or Assay. Number	:	21M02222-3
Refractive Index (R)	:	1.55-0.50i(1.33)[1.55-0.50(1.550 - 0.500i),1.33(1.333)]
Refractive Index (B)	:	1.55-0.50i(1.33)[1.55-0.50(1.550 - 0.500i),1.33(1.333)]

Median Size	:	31.79779(µm)
Mean Size	:	50.05490(µm)
R Parameter	:	2.4746E-2
Chi Square	:	0.000336
Diameter on Cumulative %	:	(1)5.000 (%)- 4.6164(µm)
	:	(2)10.00 (%)- 7.5648(µm)
	:	(3)20.00 (%)- 12.3589(µm)
	:	(4)30.00 (%)- 17.3798(µm)
	:	(5)40.00 (%)- 23.6507(µm)
	:	(6)60.00 (%)- 42.1622(µm)
	:	(7)70.00 (%)- 55.6105(µm)
	:	(8)80.00 (%)- 75.2508(µm)
	:	(9)90.00 (%)- 115.9196(µm)
	:	(10)95.00 (%)- 168.0912(µm)

Data Name	Graph Type	Sample Name	Median Size
202106220935045		Z05752 21M02222-3	31.79779(µm)
202106220935046		Z05752 21M02222-3	31.27826(µm)
202106220936047		Z05752 21M02222-3	31.23599(µm)

Remarks 1	:	
Project #	:	Z05752 04683Z
Preparation	:	
Operator	:	A. Glass



No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)	No.	Diameter(µm)	q(%)	UnderSize(%)
1	0.011	0.000	0.000	25	0.296	0.000	0.000	49	7.697	1.818	10.231	73	200.000	1.383	96.821
2	0.013	0.000	0.000	26	0.339	0.000	0.000	50	8.816	2.219	12.450	74	229.075	1.217	98.038
3	0.015	0.000	0.000	27	0.389	0.000	0.000	51	10.097	2.662	15.113	75	262.376	1.052	99.090
4	0.017	0.000	0.000	28	0.445	0.000	0.000	52	11.565	3.134	18.246	76	300.518	0.585	99.675
5	0.020	0.000	0.000	29	0.510	0.000	0.000	53	13.246	3.585	21.831	77	344.206	0.325	100.000
6	0.022	0.000	0.000	30	0.584	0.000	0.000	54	15.172	3.956	25.787	78	394.244	0.000	100.000
7	0.026	0.000	0.000	31	0.669	0.000	0.000	55	17.377	4.208	29.996	79	451.556	0.000	100.000
8	0.029	0.000	0.000	32	0.766	0.000	0.000	56	19.904	4.352	34.348	80	517.200	0.000	100.000
9	0.034	0.000	0.000	33	0.877	0.105	0.105	57	22.797	4.433	38.780	81	592.387	0.000	100.000
10	0.039	0.000	0.000	34	1.005	0.140	0.245	58	26.111	4.503	43.284	82	678.504	0.000	100.000
11	0.044	0.000	0.000	35	1.151	0.172	0.417	59	29.907	4.594	47.877	83	777.141	0.000	100.000
12	0.051	0.000	0.000	36	1.318	0.203	0.620	60	34.255	4.700	52.577	84	890.116	0.000	100.000
13	0.058	0.000	0.000	37	1.510	0.237	0.857	61	39.234	4.814	57.391	85	1019.515	0.000	100.000
14	0.067	0.000	0.000	38	1.729	0.278	1.135	62	44.938	4.921	62.311	86	1167.725	0.000	100.000
15	0.076	0.000	0.000	39	1.981	0.322	1.457	63	51.471	4.936	67.248	87	1337.481	0.000	100.000
16	0.087	0.000	0.000	40	2.269	0.370	1.827	64	58.953	4.829	72.077	88	1531.914	0.000	100.000
17	0.100	0.000	0.000	41	2.599	0.424	2.251	65	67.523	4.582	76.658	89	1754.613	0.000	100.000
18	0.115	0.000	0.000	42	2.976	0.488	2.738	66	77.339	4.186	80.844	90	2009.687	0.000	100.000
19	0.131	0.000	0.000	43	3.409	0.567	3.305	67	88.583	3.670	84.514	91	2301.841	0.000	100.000
20	0.150	0.000	0.000	44	3.905	0.668	3.973	68	101.460	3.070	87.585	92	2636.467	0.000	100.000
21	0.172	0.000	0.000	45	4.472	0.800	4.773	69	116.210	2.460	90.045	93	3000.000	0.000	100.000
22	0.197	0.000	0.000	46	5.122	0.971	5.744	70	133.103	2.054	92.099				
23	0.226	0.000	0.000	47	5.867	1.194	6.938	71	152.453	1.778	93.877				
24	0.259	0.000	0.000	48	6.720	1.475	8.413	72	174.616	1.561	95.438				

Hazen Research Inc.

APPENDIX B – CALCULATIONS

Job Name: ToBV WTP
Job Number: 1133e
Date: 9/10/2021

TOWN OF BUENA VISTA
CHLORINE CONTACT TIME CALCULATION - CARTRIDGES

FLOW PARAMETERS

Flow	2.5	MGD
	1,736	gpm

With UV

Section	Minimum Operating Volume *(gal)*	Baffle Factor	Effective Volume *(gal)*	Flow *(gpm)*	Detention Time *(min)*	Free Chlorine Residual *(mg/L)*	CT_{CALC} *(min*mg/L)*	pH	Temp *(deg C)*	Giardia $CT_{99.9}$ *(min*mg/L)*	Giardia Inactivation *(Log)*	Virus $CT_{99.9}$ *(min*mg/L)*	Virus Inactivation *(Log)*
Clearwell	18,000	0.6	10,800	1,736	6.2	1.0	6.22	8.0	10	162	0.12	6.0	4.15
										Subtotal	0.12	Subtotal	4.15
										Credit	3.0	Credit	0.0
										Total	3.1	**Total**	4.1
										Required	3.0	Required	4.0

Without UV

Section	Minimum Operating Volume *(gal)*	Baffle Factor	Effective Volume *(gal)*	Flow *(gpm)*	Detention Time *(min)*	Free Chlorine Residual *(mg/L)*	CT_{CALC} *(min*mg/L)*	pH	Temp *(deg C)*	Giardia $CT_{99.9}$ *(min*mg/L)*	Giardia Inactivation *(Log)*	Virus $CT_{99.9}$ *(min*mg/L)*	Virus Inactivation *(Log)*
Clearwell	80,000	0.6	48,000	1,736	27.6	1.0	27.65	8.0	10	162	0.51	6.0	18.43
										Subtotal	0.51	Subtotal	18.43
										Credit	2.5	Credit	0.0
										Total	3.0	**Total**	18.4
										Required	3.0	Required	4.0

Legend

Input
Calculation
Linked Cell

Reference

https://www.colorado.gov/pacific/sites/default/files/WQ-ENG-AppendixA%20Log%20Inactivation%20Brochure%202009.pdf

ToBV Preliminary Design Report
Coagulant - Aluminum Chlorohydrate (ACH)

Specific Gravity	1.3	g/mL
Specific Weight	11	lb/gal
% Solution	50.0	%

*** Dual tanks!**

Required 30-Day Coagulant Storage Based on Dose at 2.5 MGD

Flowrate		Dose *mg/L*	Chemical Feed Rate *gal/day (100% Solution)*	Chemical Feed Rate *gal/day (50% Solution)*	Chemical Feed Rate *gal/hr (50% Solution)*	30-Days of Storage *gallons*
2.5	1,736	40.0	75	150	6	4,512
2.5	1,736	30.0	56	113	5	3,384
2.5	1,736	20.0	38	75	3	2,256
2.5	1,736	15.0	28	56	2	1,692
2.5	1,736	10.0	19	38	2	1,128

Required 30-Day Coagulant Storage Based on TOC at Assorted Flows

Flowrate		TOC *mg/L*	Coagulant Dose *mg/L*	Chemical Feed Rate *gal/day (100% Solution)*	Chemical Feed Rate *gal/day (50% Solution)*	30-Days of Storage *gallons*
1.5	1,042	2.0	11	13	26	772
1.3	868	2.0	11	11	21	643
0.5	347	2.0	11	4	9	257
1.5	1,042	3.0	17	19	39	1,157
1.3	868	3.0	17	16	32	964
0.5	347	3.0	17	6	13	386
1.5	1,042	4.5	26	29	58	1,736
1.3	868	4.5	26	24	48	1,447
0.5	347	4.5	26	10	19	579
Ratio of Coagulant to TOC		5.7				

About 5.7 mg/L of coagulant is needed to remove every 1 mg/L of TOC in the raw water. Dose calculations were made based on the average TOC values seen in the water, which is 1.13 mg/L. During spring runoff, TOC concentrations are typically higher.

Potassium Permanganate Usage and Storage Calculations

Description	Value	Unit	Notes
WTP Parameters			
Average Capacity	1,380,000	gpd	
Maximum Capacity	2,500,000	gpd	
Chemical Parameters			
Purpose	Oxidation		
Solution Concentration	3%	by weight	SDS shows 1.020 g/cm^3 for 3% $KMnO_4$ solution
Specific Gravity of Solution	1.020		SDS shows 1.020 g/cm^3 for 3% $KMnO_4$ solution
Pounds per gallon of solution	**0.26**	**lbs/gal**	Specific Gravity * Lbs of Water in Gallon * Strength
Estimated Average Usage (MGD)			
Flow Rate	1,380,000	gpd	
Solution dosing rate	0.50	mg/L	Operator input
Chemical use	**6**	lbs/day	lbs chemical = Q (MGD) * dose (mg/L) * 8.34
	173	**lbs/month**	lbs/day * days in month (30)
Storage Requirements (Dry Chemical)			
Storage Type	pails		
Storage Capacity per pail	55.125	lbs	Manufacturer lists 55.125 lb per pail (97% KMnO4)
Storage Capacity per drum	330.750	lbs	Manufacturer lists 330.75 lb per drum (97% KMnO4)
Storage needed for Peak Demand	6	lbs/day	
Storage needed for Peak Month	**138**	**lbs/month**	30 days of peak demand at 80% of peak flow rate
	2.6	pails	
	0.4	drums	
Storage Capacity, each	55	lbs	Manufacturer lists 55.125 lb per pail (97% KMnO4)

Legend

Input
Calculation
Linked Cell

Flocculation				
Variable	**Description**	**Value**	**Unit**	**Notes**
Flow Rate	**Per Train**	2.5	**MGD**	
Length	Per Train	15	feet	
Width	**Per Train**	15	**feet**	
Height 1	**Per Train**	15.5	feet	
Height 2	**2 ft freeboard**	17.5	**ft**	
Splitter Box Area	unused volume p	0.0	sqft	
Volume 1	**Per Train**	3488	**feet cubed**	**Based on height 1**
Capacity 1	Per Train	26090	gal	
Detention Time 1	**Per Train**	30.1	**min**	
Volume 2	Per Train	3938	feet cubed	based on height 2
Capacity 2	**Per Train**	29456	**gal**	
Detention Time 2	Per Train	33.9	min	
Minimum Detention Time		30	**min**	
Maximum Flow Rate	Per Train	1.25	MGD	Based on min detention time
Maximum Flow Rate	**Total**	2.50	**MGD**	**Based on min detention time**
Effluent Pipe Diameter		2	feet	24 inches
Pipe Area		3.1	**ft^2**	
Flow Rate		1.9	feet^3/sec	
Effluent Velocity		0.62	**ft/s**	**no less than 0.5 or greater than 1.5 ft/s**
Effluent Velocity Design Criteria		1.5	ft/s	
Required Pipe Area		1	**ft2**	
Required Pipe Diameter		15	inches	
Flow Rate	**Per Train**	3.05	**MGD**	
Flow Rate	Total	6.09	MGD	

Legend
Input
Calculation
Linked Cell

TOWN OF BUENA VISTA
CHLORINE CONTACT TIME CALCULATION - MEMBRANES

FLOW PARAMETERS

Flow	2.5	MGD
	1,736	gpm

Section	Minimum Volume *(gal)*	Baffle Factor	Effective Volume *(gal)*	Flow *(gpm)*	Detention Time *(min)*	Free Chlorine Residual *(mg/L)*	CT_{CALC} *(min*mg/L)*	pH	Temp *(deg C)*	Giardia $CT_{99.9}$ *(min*mg/L)*	Giardia Inactivation *(Log)*	Virus $CT_{99.9}$ *(min*mg/L)*	Virus Inactivation *(Log)*
Clearwell	18,000	0.6	10,800	1,736	6.2	1.0	6.22	8.0	10	162	0.12	6.0	4.15
						*add 20 to 30% operating vlume				Subtotal	0.12	Subtotal	4.15
										Credit	3.0	Credit	0.0
										Total	3.1	**Total**	4.1
										Required	3.0	Required	4.0

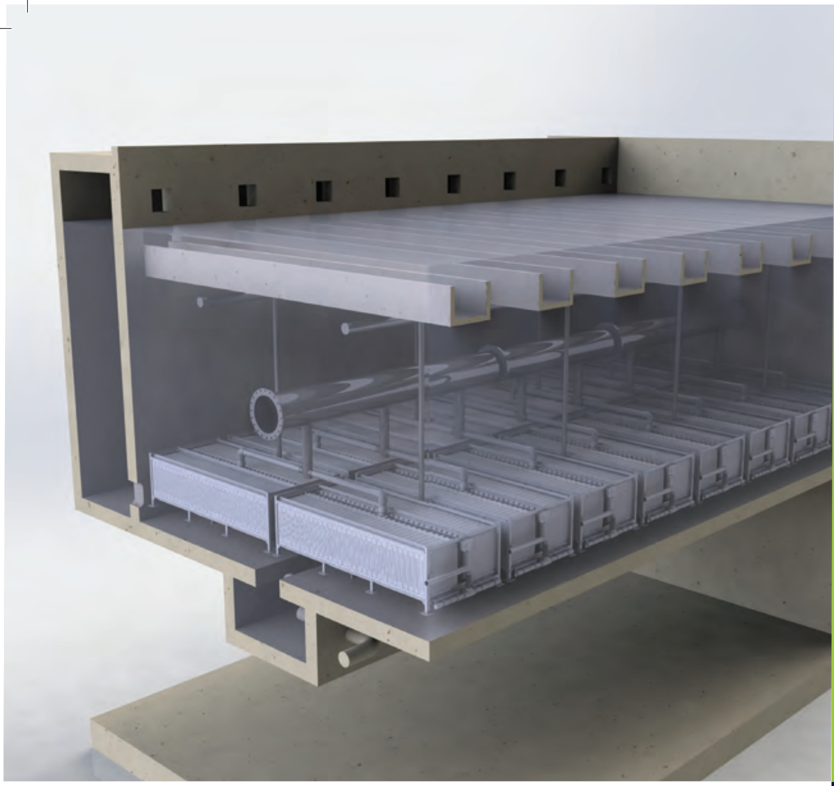
Legend

Input
Calculation
Linked Cell

Reference

https://www.colorado.gov/pacific/sites/default/files/WQ-ENG-AppendixA%20Log%20Inactivation%20Brochure%202009.pdf

APPENDIX C – BUDGETARY EQUIPMENT INFO



solutions for drinking water facilities

D.O.V.E.[1] finds 75% of Colorado surface water plants have a Giardia issue

[1]*CDPHE Disinfection Outreach Verification Effort*

get membrane quality water – delivered without the headaches. contact us today.

In the past, low pressure membranes promised to improve water quality and eliminate pathogens in municipal water supplies, but early generations were costly. This led to designs intended to maximize flux but the tradeoff was complexity for backwashing and cleaning and a reduced membrane life.

Now SUEZ has the solution to these challenges. SUEZ's Membrane Gravity Filter (MGF) provides several benefits including:

- elimination of chemical cleaning
- high recovery and infrequent backwashing
- extended membrane life
- membrane quality water delivered simply

"SUEZ's MGF helped us rehab our filters and increase our giardia log removal credit from CDPHE. This let us avoid a costly clearwell reconstruction."

– Bill Greco, Glacier Club - Durango, CO

For more information on SUEZ's MGF, contact:

Grant MacInnis, SUEZ Water Technologies & Solutions
(720) 855-7296 – grant.macinnis@suez.com

Bill Peretti, Coombs Hopkins
(303) 477-1970 – bill@chcwater.com

COOMBS-HOPKINS

suez

ready for the resource revolution

Water Technologies & Solutions

budget proposal for the

Buena Vista Membrane Gravity Filter Budget Proposal

august 2021

proposal number: 11231971gm

submitted by:
Grant MacInnis
2913 Quitman St.
Denver, CO 80212
grant.macinnis@suez.com
303-396-9532

local representation by:
Coombs Hopkins
Bill Peretti
bill@chcwater.com

note: See end of this proposal for a list of SUEZ Company trademarks that might appear in this document.

table of contents

1 technical and engineering details

1.1 basis of design

This proposal reflects SUEZ supplying a ZeeWeed Membrane Gravity Filter (MGF) retrofit to the basins at the Buena Vista WTP..

This proposal is based on the following design values

design conditions	
design minimum temperature	5°C
MGF design capacity (net) with one filters out of service (N-1)	2.5 MGD
recovery (at design capacity)	> 98%

The plant is designed assuming that no streams such as backwash or chemical wastes from the membrane system or any other unit operations in other parts of the plant are directly or indirectly recycled back ahead of the membrane system.

permeate water quality

parameter	treated water
turbidity (NTU)	≤ 0.1 NTU 95% of the time

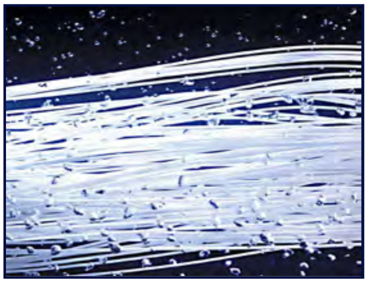
note 1: All guarantees are contingent upon proper maintenance, calibration and service of instruments and other related equipment as per SUEZ and original equipment manufacturer's instruction.

microbiological removal efficiencies

parameter	treated water
log removal value (LRV) giardia and crypto	≥ 3.0 Log

2 system process description and scope

2.1 Membrane Gravity Filtration with ZeeWeed 1000



ZeeWeed water treatment is a process technology that produces high quality treated water by filtering water through SUEZ Water Technologies & Solutions' proprietary and patented immersed ZeeWeed ultrafiltration membranes. ZeeWeed 1000 series membrane utilize "Outside-In" flow through a hollow-fiber membrane. The small pore size of the ultrafiltration membrane excludes particulate matter from the treated water.

The Membrane Gravity Filter have ZeeWeed® 1000 ultrafiltration membranes at its heart. The membranes replace the solids separation function of granular filter media in drinking water systems.

ZeeWeed® UF membranes operate under gravity, drawing clean water to the inside of the membrane fiber (outside-in flow path), while keeping impurities out.

The microscopic membrane pore size provides an extra measure of public health protection, removing a large percentage of impurities, and providing greater than 3-log removal of harmful pathogens such as Giardia cysts and Cryptosporidium oocysts.

Like a media filter, the membranes use gravity to produce filtrate, and because they operate under such low pressure, with a high membrane surface area, solids are not driven into the membrane pores to cause fouling, unlike other membrane systems. This eliminates complex, expensive and time consuming cleans.

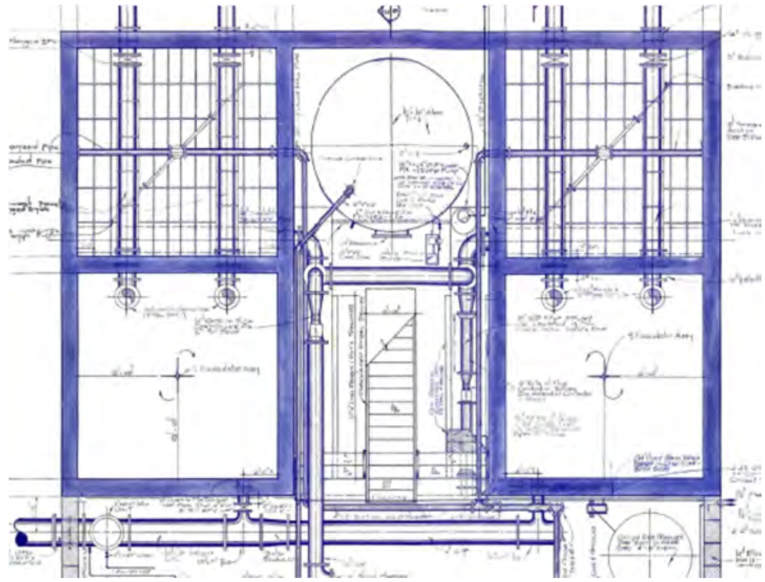
Operation is very simple. Feed flows into the membrane tank, either by pumping or gravity. The water is then filtered by the membrane and flows by gravity to the customer's treated water storage tank.

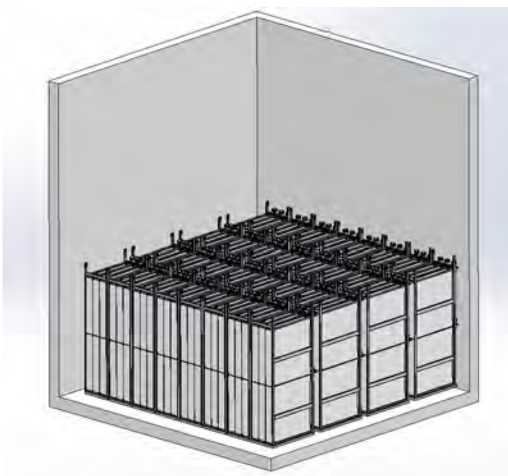
Similar to a media filter, membranes are backwashed from 1 to 2 times per day to push off solids that have built up during operation. The customer's treated water supply is used for backwashing, with a small amount of hypochlorite added. During backwashing, air is introduced at the bottom of the membrane modules to create turbulence along the membrane surface. Rising air bubbles scour and clean the outside of the membrane fibers. At the end of a backwash, the membrane filters are drained to the waste holding tank, refilled with feed, and filtration resumes..

2.2 proposed MGF system configuration

The proposed MGF design for the WTP retrofit would populate each of the basins with ZeeWeed 1000 modules. These cassettes are designed and sized such that they can fit in the tanks of the existing filters with minimal changes to the tank design.

The retrofit can happen such that most filters can continue to operate nearly uninterrupted while 1 of the filters is retrofitted to MGF at a time.





MGF membrane configuration in an existing filter

Parameter	
existing basin dimensions	12’ W x 12’L x ~10.5’ SWD
type of membrane	ZeeWeed 1000
module surface area	550 ft^2
number of basins	4

ZeeWeed 1000 membrane

2.3 scope of supply by SUEZ

The following scope is included for the membrane gravity filter water treatment.

Electrical rating on all motors is 460V / 3ph / 60 Hz. Single phase power requirement is 120V.

Please note that the proposed equipment and instrumentation quoted is to be installed in a NFPA 820 non classified area.

All devices will be SUEZ standard devices and the proposed equipment will be supplied to SUEZ specifications. Any changes to the proposed equipment to meet the Buyer's specification, including custom tag numbering, will require re-evaluation.

Equipment will be **supplied loose shipped** unless otherwise noted.

- ZeeWeed 1000 Membrane Modules and Cassettes
- Filtrate and backwash automatic and manual valves.
- Membrane header to join to customer's existing backwash and filtrate piping.
- Air Scour Header
- Membrane Air Scour Blowers
- Sodium Hypochlorite dosing system
- Compressed Air System
- Instrumentation Integral to ZeeWeed System not already available with customer system.
- Electrical and Mechanical Engineering Submittals
- PLC Control System
- Operation & Maintenance Manuals
- Installation, Commissioning and Start-up Assistance
- Operator Training
- Lifecycle Services and Remote Monitoring

2.4 customer equipment to be supplied by customer and reused by SUEZ

The following equipment is assumed to be suitable to be reused for the MGF system, or will be supplied by the customer.

- Feed, drain and effluent piping
- Backwash Pumps
- Backwash waste tank.
- Filtered water tank.
- Installation and interconnecting piping

3 commercial offer

3.1 budgetary pricing

Pricing for the proposed equipment and services as described in this budget proposal:

MGF system price **$ 1,700,000 USD**

All pricing is based on the operating conditions and influent analysis detailed in section 1. The pricing herein is for budgetary purposes only and does not constitute an offer of sale.

3.2 equipment shipment and delivery

Equipment shipment is estimated at 26 weeks after order acceptance. The Buyer and Seller will arrange a kick off meeting after contract acceptance to develop a firm shipment schedule.

typical drawing submission and equipment shipment schedule

		8-12 weeks	2-3 weeks	26 - 30 weeks		2 weeks
acceptance of PO						
submission of drawings						
drawings approval						
equipment manufacturing						
equipment shipment						
plant operations manuals						

The delivery schedule is presented based on current workload backlogs and production capacity. This estimated delivery schedule assumes no more than two weeks for Buyer review of submittal drawings. Any delays in Buyer approvals or requested changes may result in additional charges and/or delay to the schedule.

3.3 freight

The following freight terms used are as defined by INCOTERMS 2010.

All pricing is CIP designated to site. Delivery to the project site is conditional upon provision of access roads of a nature that will permit access by tractor-trailers. Off-loading and positioning of equipment at the job site is not included.

3.4 bonds

Performance or Payment Bonds are not included in the system price. These bonds can be purchased on request but will be at additional cost.

3.5 pricing notes

- All prices quoted are in **USD**.
- Any applicable sales or value added tax is not included.
- The Buyer will pay all applicable Local, **State/Provincial**, or **Federal** taxes and Duties.
- The equipment delivery date, start date, and date of commencement of operations are to be negotiated.
- Commercial Terms and Conditions shall be in accordance with Seller's Standard Terms and Conditions of Sale.

3.6 conditional offering

Buyer understands that this proposal has been issued based upon the information provided by Buyer, and currently available to Seller, at the time of proposal issuance. Any changes or discrepancies in site conditions (including but not limited to system influent characteristics, changes in Environmental Health and Safety ("EH&S") conditions, and/or newly discovered EH&S concerns, Buyer's financial standing, Buyer's requirements, or any other relevant change, or discrepancy in, the factual basis upon which this proposal was created, may lead to changes in the offering, including but not limited to changes in pricing, warranties, quoted specifications, or terms and conditions. Seller's offering in this proposal is conditioned upon a full Seller EH&S, and Buyer financial review.

SUEZ Water Technologies & Solutions
confidential and proprietary information

The following are trademarks of SUEZ Water Technologies & Solutions and may be registered in one or more countries:

InSight, ZeeWeed and ZENON.

APPENDIX D – HGE REPORT

Gorrell Meadows Horizontal Well Cost Estimate

TO: Richard Hood/JVA Consulting Engineers

COPIES:

FROM: Courtney Hemenway

DATE: September 14, 2021

RESPOND BY:

Hemenway Groundwater Engineering (HGE) was contracted by the JVA Consulting Engineers (JVA) to provide an analysis of the viability and potential costs to install horizontal well(s) in the Gorrell Meadows alluvial aquifer system that currently provides water supply to the Town of Buena Vista (Town), Colorado. The town currently operates an infiltration gallery in the Gorrell Meadows alluvial aquifer with the location shown in Figure 1 (from Providence Infrastructure Consultants). The existing infiltration gallery or horizontal wells currently do not produce sufficient flow to meet future water supply demands for the Town. In 2019, HGE and Town staff investigated the alluvial materials beneath the meadows area by conducting several shallow (10- to 15-feet deep) “pot holes” with a town backhoe. In addition, eight monitoring wells were installed in December 2019 and equipped with water level transducers and data loggers to evaluate the alluvial groundwater system beneath the Gorrell Meadows. The data loggers began the collection of water level data in each of the monitoring wells in January 2020. Water level data has been collected continuously in the wells since that date.

A virtual meeting was conducted with staff from the Town, JVA, Wright Water Engineers, and HGE. The results from the meeting indicated that there are constraints imposed by water rights limitations that restrict the installation of vertical wells in the Gorrell Meadows area. This was further confirmed in conversations with Shawn Williams from the Town. In addition, the installation of horizontal wells is limited to two quarter sections as shown in Figure 1(note: the location of the horizontal wells in this figure were preliminary locations that have been revised).

HGE contacted Becky Dewind of Dewind One-Pass Trenching (Dewind) to discuss the potential viability of installing horizontal wells using Dewind’s One-Pass installation procedure. Information from the pot holing investigation and monitoring well installations were provided to Dewind. Dewind indicated that the geology with large cobbles up to two feet in diameter that were exposed during the pot holing would be challenging, but the installation of the wells could be completed. Becky noted that they would use a larger machine than normally required to install a 20-foot-deep horizontal well in order to accommodate the large cobbles that would be encountered at the site. Dewind just recently completed a horizontal well in Steamboat Springs in similar geologic conditions that was highly productive.

The depth of 20 feet from the horizontal piping was selected since deeper installations would become increasingly difficult to install based on the geology. At a depth of 20 feet, the new horizontal wells would be 10 feet deeper than the majority of the existing infiltration gallery. The additional depth would increase the available driving head to the well and increase the rate and duration of flow available from the well.

The proposed construction of the horizontal wells would be completed with up to 500 feet of horizontally placed 6-inch diameter HDPE slotted pipe. The well would be completed on one end with a 16-inch-diameter vertical sump, and at the opposite end the 6-inch-diameter HDPE would come to ground surface and be used as a clean-out for the system. The 16-inch sump would be used to install a submersible pump to produce water from the horizontal section of the well. Dewind's installation procedure installs the vertical sump and the horizontal piping with bedding gravel in a one-pass continuous process. The horizontal piping would be placed with clean, washed 3/8-inch pea gravel from the base of the trench (20 feet) to approximately 5 feet below grade. The area from 5 feet to ground surface would be filled with native fill from the excavation.

The construction of the horizontal well with a vertical sump for production from the well would provide control of flow from the Gorrell Meadows alluvial aquifer system. The evaluation of the monitoring well data from the eight monitoring wells installed in the Gorrell Meadows area indicated that the infiltration gallery significantly controls the alluvial groundwater system beneath the Gorrell Meadows. The continuous flow from the infiltration regulates and reduces the storage of water provided by the flood irrigation that the Town conducts to recharge the alluvial aquifer system with existing surface water rights. Using submersible pumps to produce water from the aquifer, rather than gravity flow, would provide the positive regulation of flow and storage within the aquifer.

Currently, the infiltration flows continuously throughout the year, regardless of water system demands. As water system demands increase, flow is collected from the infiltration gallery for disinfection and distribution to the potable water system for Buena Vista. By not controlling the flow from the infiltration gallery during periods of lower demand, there is a significant volume of groundwater that is not being captured and stored in the aquifer for later use in high-demand periods.

By adding controls to the flow from the infiltration gallery, there is the potential to significantly increase the storage of water within the alluvial aquifer system at the Gorrell Meadows. By increasing the storage volume in the aquifer, higher flow rates and greater volumes would be available from the aquifer during high-demand periods. By controlling the outflow from the aquifer, the estimated increased volume of available storage would be 108 acre-feet (see HGE Technical Memorandum *Gorrell Meadows Alluvial Monitoring Well Report January 2020 to May 6, 2021* dated June 3, 2021).

HGE evaluated the installation of two to three horizontal wells in the Gorrell Meadows area. The three locations are shown in Figure 2. Two locations are situated in the irrigated portion of the Gorrell Meadows on the north side of Cottonwood Creek. The third location is shown on the south side of Cottonwood Creek on Town property adjacent to the existing water storage tank. One proposed location on the north side of Cottonwood Creek would be placed downgradient of the existing infiltration gallery. As noted, the depth of the new horizontal well would be 20 feet deep, or 10 feet deeper that the existing infiltration gallery depth. The proposed well would extend across the entire alluvial aquifer system, perpendicular to Cottonwood Creek. That orientation would maximize the interception of downgradient water flow through the alluvial aquifer. Evaluation of the monitoring well data (see Technical Memorandum dated June 3, 2021) indicated that there is minimal influence from Cottonwood Creek in the immediate area of the Gorrell Meadows and that water in the aquifer at that location is from downgradient flow through the aquifer and imposed recharge from the irrigation of the meadows. The second location shown on the north side of Cottonwood Creek (Figure 2) would be installed if the production from the first well is limited and the location on the south side of Cottonwood Creek is not feasible. The location of the well would be parallel to Cottonwood Creek to intercept any additional flow not collected from the first well that is perpendicular to the river.

The third proposed well location is situated on the south side of Cottonwood Creek. The review of limited geologic and lithologic data indicates similar alluvial materials as identified on the north side of Cottonwood Creek. Location of this well would provide additional interception of the downgradient flow through the alluvial aquifer system and not interfere with the operation of the wells on the north side of the river and thereby provide additional capacity to the Town's water supply. If the wells produce 1,000 gallons per minute (gpm) to more than 1,500 gpm, the location of the southern well would allow for significant redundancy to the water supply system. Future water supply demands have been estimated at 2,000 gpm.

Cost Estimate

HGE provided geologic and lithologic data to Becky Dewind to enable her to provide a cost estimate to install up to three horizontal wells for the Town. Becky provided a cost estimate with general conditions for the installation of the wells. The cost estimate and general conditions are attached. If two wells are installed the cost per well would be $350,000. If three wells are installed, the per well cost would be $315,000.

The cost estimate provides for the main components for installing the wells. However, additional costs would be incurred for the gravel bedding of the wells and for equipment required to be provided to Dewind during the well installations. Costs for the gravel were provided from ACA Products of Buena Vista. Each well would require approximately 550 cubic yards of bedding gravel. Costs for 550 cubic yards of washed 3/8-inch pea gravel would be $35,000.

Dewind requires that the Town provide an excavator with a reach up to 20 feet and two 4 to 5 yard front end loaders. The loaders are required to move and place the gravel bedding into the feed hopper during the installation of the wells. Joe Pedre contacted Four Rivers equipment to obtain cost estimates for a week's rental of the equipment. Costs for rental of the equipment for one week would be $6,500.

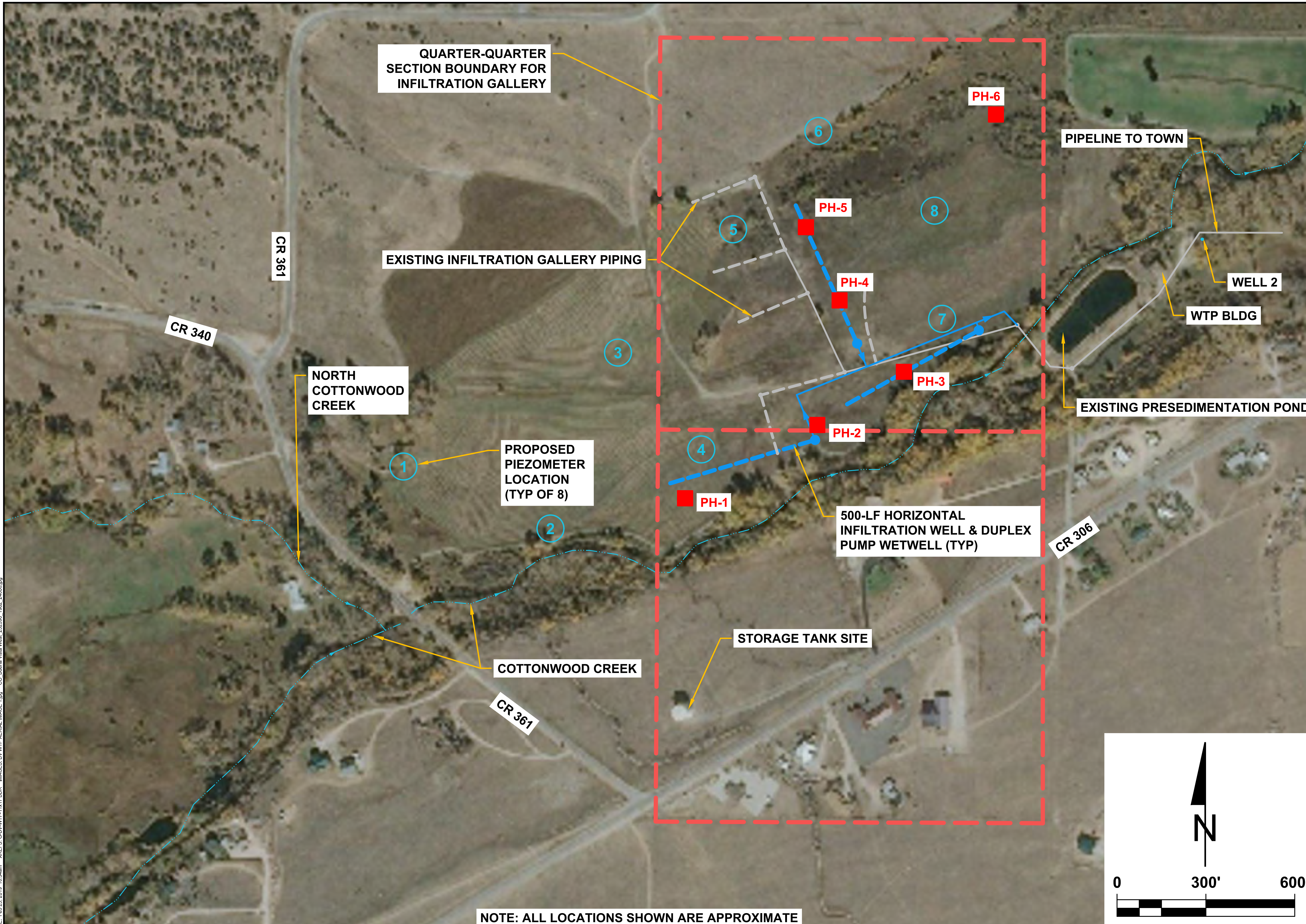
Engineering fees for HGE during the permitting, field observation of the well installations, testing of the wells, and providing a well completion report for the wells would be $25,000 to $30,000. Testing of the wells would include a 3.5-hour variable-rate pumping test and a 72-hour continuous-rate pumping test. At the conclusion of the 72-hour test, a full-range water quality sample would be collected. Costs for the water sample would be approximately $4,000 and **are not** included in the estimate.

A summary of the costs is shown in the following table.

Summary of Costs for Town of Buena Vista Horizontal Wells			
Item	**Cost per Well**	**Cost for 2 Wells**	**Cost for 3 Wells**
Well Installation	$315,000 (3) or $350,000 (2)	$700,000	$945,000
Gravel Bedding	$35,000	$70,000	$105,000
Rental Equipment		$6,500	$13,000
Well Testing	$25,000	$50,000	$75,000
Permitting and Engineering		$25,000	$30,000
Total Costs		**$851,500**	**$1,168,000**

Costs for final equipping of the wells, well head facilities, transmission piping, electrical service fees, and other associated costs to incorporate the wells into the Town's water supply and treatment facilities are not included.

FIGURES



PROVIDENCE INFRASTRUCTURE CONSULTANTS

FIGURE 1 - POTHOLE & PIEZOMETER LOCATIONS

TOWN OF BUENA VISTA, COLORADO
WATER TREATMENT FEASIBILITY STUDY

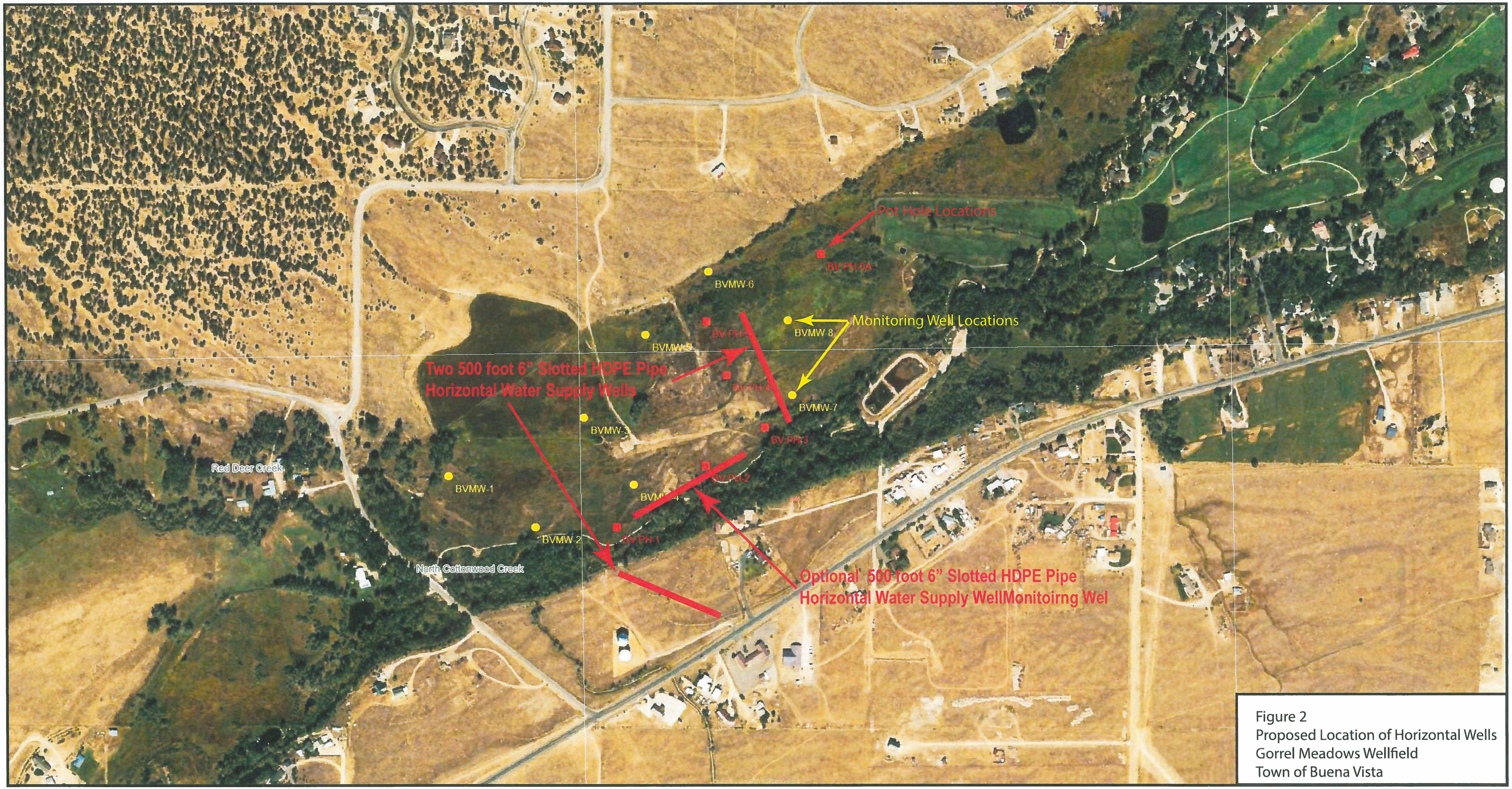


Figure 2
Proposed Location of Horizontal Wells
Gorrel Meadows Wellfield
Town of Buena Vista

DEWIND COST ESTIMATE

DEWIND
ONE PASS TRENCHING

9150 96th Street
Zeeland, Michigan 49464
616-875-7580
DEWINDONEPASSTRENCHING.COM

September 8, 2021
Courtney Hemingway
Hemingway Groundwater Engineering, Inc.
17011 Lincoln Avenue, PMB 416
Parker, CO 80134

COST ESTIMATE FOR HORIZONTAL IRRIGATION SYSTEM
SITE IN COLORADO – BUENA VISTA

Mobilization, Assembly, Demobilization of MT 2000
120,000.00

Installation of Three 20' deep x 500 linear foot long x 24" wide Horizontal Irrigation as follows:
One Vertical 16"diameter sump supplied and installed at the beginning of the trench.
500 linear feet of 6" slotted HDPE SDR 11 pipe pre-connected to the vertical sump and installed at the bottom of the trench 35' deep.
Pipe and cut trench simultaneously backfilled with supplied washed pea gravel to grade. System terminated with solid 6" HDPE pipe from 20' blg to grade to be used as a clean out.
$350,000 each for 2 systems minimum
$315,000 each for 3 systems minimum

The test pits show very aggressive rocks and gravel. No conclusive soils data to depth. Dewind has assumed that the test pits are representative of the soils to depth.

DeWind Standard Assumption apply to this cost estimate

DEWIND ONE-PASS TRENCHING STANDARD ASSUMPTIONS

COLLECTION TRENCHES GWCT OR BACKFILLED TRENCHES:

** **SOILS CONDITIONS TO BE MOSTLY SAND, CLAY OR OTHER NON-CONSOLIDATED SOILS. DEWIND DOES NOT EXPECT TO ENCOUNTER ANY LARGE COBBLES, SMALL OR LARGE BOULDERS OR HARD ROCK LAYERS OR BURIED RUBBLE.**

** **WATER TABLE MORE THAN 7' BLG OR GREATER.**

Contractor to prepare the work platform minimum 40' feet wide depending on the stone feed options, level side to side and a maximum of 6% grades. Work platform must be stable and able to withstand 25 psi 500,000 lb track machine.
If fill is required to create a work platform, it must be clean without large rocks, cobbles or construction debris.

****ONE-PASS INSTALLATIONS NEAR BUILDINGS OR STRUCTURES WILL BE PROTECTED BY SHEETING IF REQUIRED AND WILL BE INSTALLED BY OTHERS. DEWIND WILL NOT BE LIABLE FOR UNDERMINING OF ANY NEARBY STRUCTURES OR SUPPORTING WALLS OR BERMS DURING THE INSTALLATION OF THE COLLECTION TRENCH.**

~~**DEWATERING OF THE MANHOLE AREA AND STEEL SHEETING OF THE START OF THE EXCAVATION WILL NEED TO BE PROVIDED FOR THE TRENCHER TO START A SYSTEMS INSTALLATION OFF OF A INSTALLED MANHOLE.**~~

BACKFILL MEDIA PROVIDED BY OTHERS.
BACKFILL SHOULD BE WASHED STONE AND SAND MIXED.

SUPPORT EQUIPMENT PROVIDED BY OTHERS;

ONE LARGE EXCAVATOR

TWO 4-5 YARD LOADERS. ONE SET OF FORKS
MANLIFT
STONE BOX
75 KW GEN SET

LARGER TRENCHES REQUIRE A CRANE FOR ASSEMBLY

** NO UNION LABOR REQUIRED.
** NO FEDERAL, STATE OR LOCAL WAGES REQUIRED.
** SITE CONDITIONS ARE LEVEL D.
** DEWIND WILL NOT BE REQUIRED TO PROVIDE PERFORMANCE BOND.

* WINTER WORK EXCLUDED.

** DEWIND WILL BE ALLOWED TO WORK ALL DAY LIGHT HOURS 7 DAYS A WEEK.

** CONTRACTOR WILL PROVIDE ANY REQUIRED SITE SAFETY, CONSTRUCTION SUPPORT, AND/OR ENGINEERING OVERSITE REQUIRED TO WORK 7 DAYS A WEEK 10 HOUR DAYS.
THE INSTALLATION OF THE COLLECTION TRENCH WILL BE CONSECUTIVE AND UNINTERUPTED WITHOUT DELAYS.

<u>CONTRACTOR IS RESPONSIBLE FOR THE FOLLOWING</u>:

** PROVIDED CLEAR ACCESS INTO THE SITE FOR THE TRENCHER AND CONTRUCTION EQUIPMENT.

** A STABLE WORK AREA AND SITE PATH FOR THE EQUIPMENT MUST BE PROVIDED.

** IF REQUIRED, THE CONTRACTOR IS RESPONSIBLE FOR THE SUPPLY AND MANAGEMENT OF CRANE MATS. WORKING OFF CRANE MATS WILL BE AN ADDITIONAL COST. TBD

** SURVEY STAKING OF THE COLLECTION TRENCH ALIGNMENTS CENTERLINE WITH AN ADDITIONAL SET OF STAKES OFF SET 20' FROM CENTERLINE.

** ALL SITE PREP AND RESTORATION INCLUDING SPOILS HANDLING BY OTHERS.

** PERMITS OR APPROVALS, ENGINEER DRAWINGS AND POST AS BUILT DRAWINGS.

** SITE RESTORATION BY OTHERS.

** DEWIND ASSUMES THE TRENCHER CAN BE POWER WASHED OFF OVER THE NEWLY INSTALLED GWCT AND WASH WATER CAN PURCULATE DOWN THRU THE SOILS. IF A WASH PAD AND MANAGEMENT OF WASH WATER IS REQUIRED THAT TASK WILL BE BY OTHERS

** SITE SAFETY AND AIR MONITORING BY OTHERS IF REQUIRED.

** ANY SUPPORT DEWIND MAY UNEXPECTEDLY NEED DURING THE INSTALLATION.

~~CANADIAN PROJECTS:~~
~~GST OR PST IS NOT INCLUDED IN THE PROPOSAL~~
~~ALL PRICES ARE IN USD~~
~~NO WINTER WORK. HAULING DURING FROST LAW SEASON EXTRA.~~
~~PERMA FROST MUST BE OUT OF THE GROUND BEFORE INSTALLATIONS~~.

** NO PERFORMANCE BONDS will not be provided– Due to the cost savings provided by utilizing the DeWind One-Pass Trenching Technology DeWind will not provide performance Bonds for GWCT's.

APPENDIX E – O&M COSTS AND OPCS

Job Name: ToBV WTP
Job Number:1133e
Date: 10/1/2021

OPINION OF PROBABLE COST				
COTTONWOOD CREEK SURFACE WATER IMPROVEMENTS ALTERNATIVE				
Description	**Quantity**	**Units**	**Unit Cost**	**Total Cost**
Division 00 and 01 - General Conditions and Requirements				
Mobilization/Demobilization	1	LS	$400,000	$400,000
			General Requirements Subtotal	**$400,000**
Division 02 - Sitework				
Site Piping	1	LS	$100,000	$100,000
Headgate and Diversion Structure Improvements	1	LS	$500,000	$500,000
Presed Pond Modifications and Site Work	1	LS	$150,000	$150,000
Residuals Pond Modifications	1	LS	$50,000	$50,000
			Sitework Subtotal	**$800,000**
Division 03 - Concrete				
Pretreatment Tanks	1	LS	$300,000	$300,000
			Concrete Subtotal	**$300,000**
Division 09 - Painting				
Pipe Coatings	1	LS	$50,000	$50,000
			Painting Subtotal	**$50,000**
Division 11 - Equipment				
Intermediate Feed Pumps	2	EA	$55,000	$110,000
Residuals Pumps	2	EA	$35,000	$70,000
Backwash Pumps	1	EA	$60,000	$60,000
MRI Floc, Plate Settler and Trac Vac System Packag	1	EA	$410,000	$410,000
Gravity Membrane System	1	EA	$2,200,000	$2,200,000
Coagulant Chemical Feed and Storage System	1	EA	$50,000	$50,000
Oxidant Chemical Feed and Storage System	1	EA	$50,000	$50,000
Sodium Hypochlorite Generation and Feed System	1	EA	$175,000	$175,000
			Equipment Subtotal	**$3,125,000**
Division 13 - Special Construction				
Pretreatment and Chemical Building	3,500	SF	$250	$875,000
			Concrete Subtotal	**$875,000**
Division 15 - Mechanical				
Ex. Building Improvements	1	LS	$150,000	$150,000
Process Piping and Fittings	1	LS	$200,000	$200,000
			Mechanical Subtotal	**$350,000**
Division 16 - Electrical				
Electrical	1	LS	$1,000,000	$1,000,000
Instrumentation and Controls	1	LS	$800,000	$800,000
			Electrical Subtotal	**$1,800,000**

Project Subtotal	**$7,700,000**
Contingency (20%)	$1,540,000
Contractor's OH&P and General Conditions (20%)	$1,848,000
Engineering, Permitting and Design (10%)	$1,109,000
Bidding and Construction Administration (5%)	$554,000
Project Total	**$12,751,000**

OPINION OF PROBABLE COST				
INFILTRATION GALLERY IMPROVEMENTS ALTERNATIVE				
Description	**Quantity**	**Units**	**Unit Cost**	**Total Cost**
Division 00 and 01 - General Conditions and Requirements				
Mobilization/Demobilization	1	LS	$150,000	$150,000
			General Requirements Subtotal	**$150,000**
Division 02 - Sitework				
Horizontal Wells for IG Expansion	1	LS	$826,500	$826,500
Site Work	1	LS	$100,000	$100,000
Site Piping	1	LS	$150,000	$150,000
			Sitework Subtotal	**$1,076,500**
Division 03 - Concrete				
Chlorine Contact Basin	1	LS	$200,000	$200,000
			Concrete Subtotal	**$200,000**
Division 09 - Painting				
Pipe Coatings	1	LS	$35,000	$35,000
			Painting Subtotal	**$35,000**
Division 11 - Equipment				
Raw Water Feed Pumps	3	EA	$55,000	$165,000
IG Transfer Pumps	2	EA	$40,000	$80,000
Cartridge Filter System	1	LS	$190,000	$190,000
Sodium Hypochlorite Generation and Feed System	1	EA	$175,000	$175,000
pH Adjustment Chemical Feed and Storage System	1	EA	$50,000	$50,000
			Equipment Subtotal	**$660,000**
Division 13 - Special Construction				
IG Treatment Building	800	SF	$250	$200,000
			Mechanical Subtotal	**$200,000**
Division 15 - Mechanical				
Process Piping and Fittings	1	LS	$125,000	$125,000
			Mechanical Subtotal	**$125,000**
Division 16 - Electrical				
Electrical	1	LS	$400,000	$400,000
Instrumentation and Controls	1	LS	$250,000	$250,000
			Electrical Subtotal	**$650,000**

Project Subtotal	**$3,096,500**
Contingency (20%)	$619,000
Contractor's OH&P and General Conditions (20%)	$743,000
Engineering, Permitting and Design (10%)	$446,000
Bidding and Construction Administration (5%)	$223,000
Project Total	**$5,127,500**

CONSULTING ENGINEERS

OPINION OF PROBABLE COST				
RECOMMENDED PROJECT ALTERNATIVE				
Description	**Quantity**	**Units**	**Unit Cost**	**Total Cost**
Division 00 and 01 - General Conditions and Requirements				
Mobilization/Demobilization	1	LS	$350,000	$350,000
			General Requirements Subtotal	**$350,000**
Division 02 - Sitework				
Site Piping	1	LS	$150,000	$150,000
Headgate and Diversion Structure Improvements	1	LS	$500,000	$500,000
Presed Pond Modifications and Site Work	1	LS	$150,000	$150,000
Residuals Pond Modifications	1	LS	$50,000	$50,000
Horizontal Wells for IG Expansion	1	LS	$826,500	$826,500
			Sitework Subtotal	**$1,676,500**
Division 09 - Painting				
Pipe Coatings	1	LS	$35,000	$35,000
			Painting Subtotal	**$35,000**
Division 11 - Equipment				
IG Transfer Pumps	2	EA	$40,000	$80,000
Backwash Pumps	1	EA	$60,000	$60,000
Residuals Pumps	2	EA	$35,000	$70,000
Gravity Membrane System	1	EA	$2,200,000	$2,200,000
Coagulant Chemical Feed and Storage System	1	EA	$50,000	$50,000
Oxidant Chemical Feed and Storage System	1	EA	$50,000	$50,000
Sodium Hypochlorite Generation and Feed System	1	EA	$175,000	$175,000
pH Adjustment Chemical Feed and Storage System	1	EA	$50,000	$50,000
			Equipment Subtotal	**$2,735,000**
Division 13 - Special Construction				
Building Addition for Chemicals	650	SF	$250	$162,500
			Concrete Subtotal	**$162,500**
Division 15 - Mechanical				
Ex. Building Improvements	1	LS	$150,000	$150,000
Process Piping and Fittings	1	LS	$125,000	$125,000
			Mechanical Subtotal	**$275,000**
Division 16 - Electrical				
Electrical	1	LS	$900,000	$900,000
Instrumentation and Controls	1	LS	$700,000	$700,000
			Electrical Subtotal	**$1,600,000**

Project Subtotal	**$6,834,000**
Contingency (20%)	$1,367,000
Contractor's OH&P and General Conditions (20%)	$1,640,000
Engineering, Permitting and Design (10%)	$984,000
Bidding and Construction Administration (5%)	$492,000
Project Total	**$11,317,000**

CONSULTING ENGINEERS

OPERATION AND MAINTENANCE COSTS
COTTONWOOD CREEK SURFACE WATER IMPROVEMENTS ALTERNATIVE

20 Year O&M Cost

Year	n	Annual Cost	2021 PW
2021	0	$ 110,200	$ 110,200
2022	1	$ 112,400	$ 109,445
2023	2	$ 114,600	$ 108,654
2024	3	$ 116,900	$ 107,920
2025	4	$ 119,235	$ 107,182
2026	5	$ 121,600	$ 106,434
2027	6	$ 124,100	$ 105,767
2028	7	$ 126,500	$ 104,978
2029	8	$ 129,100	$ 104,319
2030	9	$ 131,600	$ 103,543
2031	10	$ 259,200	$ 198,578
2032	11	$ 137,000	$ 102,199
2033	12	$ 139,700	$ 101,473
2034	13	$ 142,500	$ 100,786
2035	14	$ 145,300	$ 100,064
2036	15	$ 148,300	$ 99,445
2037	16	$ 151,200	$ 98,724
2038	17	$ 154,200	$ 98,036
2039	18	$ 157,300	$ 97,378
2040	19	$ 160,500	$ 96,747
2041	20	$ 316,000	$ 185,472
		20 Year O&M (2021 PW)	**$ 2,347,300**

Annual O&M Costs	Alternative
Electricity	$5,100
Chemical Cost	$24,930
Additional Operator Hours	$64,500
Annual Maintenance/Repairs[1]	$15,625
Annual Subtotal	**$110,155**
Other O&M Costs	**Alternative**
5 year Replacement Cost	$0
10 year Replacement Costs	$102,500

[1] Assumed at 0.5% of equipment capital cost

CONSULTING ENGINEERS

OPERATION AND MAINTENANCE COSTS
INFILTRATION GALLERY ALTERNATIVE

20 Year O&M Cost

Year	n	Annual Cost	2021 PW
2021	0	$ 79,000	$ 79,000
2022	1	$ 80,600	$ 78,481
2023	2	$ 82,200	$ 77,935
2024	3	$ 83,900	$ 77,455
2025	4	$ 85,548	$ 76,901
2026	5	$ 87,300	$ 76,412
2027	6	$ 89,000	$ 75,852
2028	7	$ 90,800	$ 75,352
2029	8	$ 92,600	$ 74,825
2030	9	$ 94,500	$ 74,353
2031	10	$ 96,300	$ 73,777
2032	11	$ 98,300	$ 73,329
2033	12	$ 100,200	$ 72,782
2034	13	$ 102,200	$ 72,283
2035	14	$ 104,300	$ 71,829
2036	15	$ 106,400	$ 71,349
2037	16	$ 108,500	$ 70,844
2038	17	$ 110,700	$ 70,380
2039	18	$ 112,900	$ 69,892
2040	19	$ 115,100	$ 69,380
2041	20	$ 117,400	$ 68,906
		20 Year O&M (2021 PW)	**$ 1,551,300**

Annual O&M Costs	Alternative (Cartridge Life = 8 Weeks)
Electricity	$14,400
Chemical	$16,811
Cartridge Disposal	$100
Additional Operator Hours	$21,500
Annual Filter Maintenance/Repairs[1]	$26,223
Annual Subtotal	**$79,033**
Other O&M Costs	**Alternative**
5 year Replacement Cost	$0
10 year Replacement Costs	$0

[1] Assumed at 0.5% of equipment capital cost

Town of Buena Vista Water Resources Master Plan

Wright Water Engineers, Inc.

October 2021

Job No. 841-068.190

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Tables

Figures

Appendix

ACRONYMS and ABBREVIATIONS

AF	acre-feet
ASR	Aquifer Storage and Recovery
ATM	Alternative Transfer Mechanism
BMP	Best Management Practice
cfs	cubic feet per second
CDPHE	Colorado Department of Public Health and Environment
CWCB	Colorado Water Conservation Board
EPA	Environmental Protection Agency
Fry-Ark	Fryingpan-Arkansas Project
gpd	gallons per day
gpm	gallons per minute
GWUDI	groundwater under direct influence (of surface water)
IWSA	Interruptible Water Supply Agreement
LIRF	Lawn Irrigation Return Flow
MDD	maximum daily demand
MG	million gallons
MGD	million gallons per day
SFE	Single Family Equivalent
SEO	State Engineer's Office
SUP	Special Use Permit
SWPP	Source Water Protection Plan
UAWCD	Upper Arkansas Water Conservancy District
USFS	United States Forest Service
USGS	United States Geological Survey
WTP	Water Treatment Plant
WWE	Wright Water Engineers, Inc.
WWTP	Wastewater Treatment Plant

CONVERSIONS

1 MG = 3.07 AF

1 cfs = 449 gpm

1 AF = 325,851 gallons

1 MGD = 1.5466 cfs-day

1 cfs for 24 hours = 646,560 gpd = 0.6466 MGD = 1.9835 AF

EXECUTIVE SUMMARY

The Town of Buena Vista has a strong portfolio of Cottonwood Creek water rights, with the irrigation season water rights having appropriation dates in the mid-1860s. The Town also has the senior non-irrigation season water right on Cottonwood Creek, the Buena Vista Water Works right.

The average-day raw water demand for the Town‘s water rights is approximately 0.6 million gallons per day (MGD). The peak-day raw water demand is approximately 1.5 MGD (2.3 cubic feet per second, [cfs]), a peaking factor of 2.5.

The Town is currently serving approximately 1,810 single family equivalents (SFEs) with one SFE providing the amount of water used by a 3-bedroom, 2-bath single family home. The average-day raw (untreated) water requirement to serve one SFE is 350 gallons per day (gpd) while the estimated peak-day demand is 830 gpd per SFE (1,500,000 gpd/1,810 SFE). Raw water demand will be the focus of this report because raw water demand is the water right demand created by the Town’s overall water users along with system losses.

Based on the Town’s current high rate of growth, the Town needs to understand the maximum number of SFEs that can reliably be served in a dry-year by the Town’s existing water rights. The peak-day water demand occurs in June or July and the total of the Town’s current water rights that will be available is estimated to be 3.98 cfs and 3.0 cfs (2.6 MGD and 1.9 MGD) in June and July, respectively. The maximum number of SFEs that the Town can currently serve with its existing water rights in a dry-year is 2,526. Given a growth rate scenario of 70 SFEs per year, the existing water rights portfolio will be at its dry-year capacity in the year 2030.

If the Town adopts and enforces conservation measures and water use restrictions in dry-years, and achieves a water use savings of 20 percent, the number of SFEs that could be served with the current supplies would increase to 3,157, extending the dry-year capacity to the year 2038.

The potential for the Town to realize future severe water stress in a dry-year scenario, based on a continued high growth rate, would appear to make it prudent to prepare a Management Plan that may involve future development and water use restrictions. This plan should be reviewed on an annual basis to assess current growth trends to determine if restrictions should be implemented.

The raw water amount diverted under the Town’s water rights less the metered potable water amount has averaged about 50 million gallons (MG) per year, an average loss of 24 percent. This “unaccounted water” is also referred to as “non-revenue water.” The Public Works Department is well aware of the loss rate and continues to investigate and implement solutions to reduce the non-revenue water. The non-revenue water is due to factors such as the aging pipeline infrastructure, undetected system leaks, and general non-revenue water use such as through hydrants or unauthorized water taps. Reductions in the unaccounted water may translate into increased SFE capacity.

As will be discussed in the following sections, production capacity limitations of the Infiltration Gallery and the supporting infrastructure compared to the maximum-day demand indicates that the infrastructure is currently at its peak capacity and infrastructure capacity is more a constraint to supporting growth than are water rights.

The Infiltration Gallery (also referred to as gallery) underlying the meadow is recharged using the 2.66 cfs Gorrel water right under its irrigation use and water is currently withdrawn, for the most part, under the 2.0 cfs Thompson Ditch water right. The summer physical production capacity of the gallery is approximately 800 gallons per minute (gpm) (1.15 MGD or 1.78 cfs). The Town's peak day demand is met by the gallery capacity, limited use of Well No. 2 and Well No. 3, and, if needed, drawdown of the water storage tanks.

The expansion and deepening of the gallery are being investigated. It is probable that an expansion of the gallery will trigger a determination that the gallery is groundwater under direct influence (GWUDI) of surface water, which will trigger a requirement for filtration treatment. Absent an expansion project, it is likely just a matter of time before the gallery water will require filtration treatment due to changing water quality regulations or a water quality test result that exceeds standards.

The existing water treatment plant (WTP), which treated Cottonwood Creek surface water, was decommissioned in 1999. Studies are underway to plan and design a rehabilitation or an upgrade of the WTP to treat both the gallery groundwater and Cottonwood Creek surface water with a treatment capacity of 2.5 MGD, the capacity needed to treat the 3.88 cfs senior water rights. An expanded and deeper Infiltration Gallery will require pumping to the upgraded WTP. The surface water diversion structure on Cottonwood Creek will also need to be rehabilitated to meet the design capacity of the WTP.

The Town's Arkansas Well No. 3, located in River Park, is currently permitted by the Office of the State Engineer (SEO) for irrigation use and a new permit will be required for municipal use. Augmentation can be from the Upper Arkansas Water Conservancy District (UAWCD) global augmentation plan or, alternatively, the Town could file an augmentation plan with newly acquired water rights. The capacity of the 8-inch casing diameter well with its existing pump is 120 gpm (0.27 cfs), or an estimated daily production of 0.17 MGD. The Colorado Department of Public Health and Environment (CDPHE) has approved plans for potable use of Well No. 3. A larger capacity pump with a discharge of approximately 225 gpm (0.5 cfs) could be installed in Well No. 3.

Site selection for an Arkansas Well No. 4 is underway with the well to be located in the River Park north of Well No. 3. A production rate similar to Well No. 3.

Recommendations:

- Water supply infrastructure is the most pressing need. The potable use of Well No. 3 is needed to provide additional supply while the WTP is being upgraded and the Infiltration Gallery is being expanded. Augmentation of Well No. 3 can be augmented most expeditiously through the UAWCD global augmentation plan.
- The site selection and construction of Well No. 4 should proceed with the anticipation of use in the potable system if water quality test results are favorable. Augmentation for Well No. 4 will also be required in order to increase infrastructure capacity.
- Continue to annually purchase Fryingpan-Arkansas (Fry-Ark) Project Water.
- Perform WTP upgrade construction for Cottonwood Creek surface water treatment prior to the construction of the Infiltration Gallery expansion on the north side of Cottonwood Creek.
- Continue the distribution system pipeline replacement program to assist in the reduction of non-revenue water.
- Adopt water conservation measures that include landscape requirements such as soil amendment specifications to facilitate more efficient irrigation.
- Continue to explore opportunities to purchase water rights and/or water storage. Without water storage opportunities, consideration of water rights on Cottonwood Creek should be limited to those equal to or senior to December 17, 1872, with irrigated land capable of dry-up. More junior water rights can be considered for acquisition if there is an opportunity to create water storage.
- The Town should continue to monitor and participate in expansion of Cottonwood Lake if the U.S. Forest Service (USFS) approves the UAWCD special use permit for expansion of the storage capacity.
- A rate study is recommended to review the current and projected income needs for both planned capital investments and operation costs considering future inflationary and growth impacts.

1.0 BACKGROUND

1.1 Goals and Objectives

This Master Plan is focused on the water resources of the Town of Buena Vista with a primary goal of identifying the number of SFEs the Town's current water rights portfolio can legally and reliably supply and to provide recommendations as to how to manage and enhance the water resources portfolio to meet the Town's short- and long-term planning projections and goals. This Master Plan provides information for infrastructure planning, but it is not intended to be used as detailed guidance for the water system infrastructure future capacity restrictions or maintenance requirements.

The scope of work performed for this Master Plan has included the following:

1. Conduct interviews with Town Staff on operations, challenges, and vision.
2. Review historic Master Plans of the Town.
3. Retrieve and present historic hydrological data on precipitation, temperature, and streamflow.
4. Compile historic demographic information around population and SFE data, consider recent growth in SFEs, and develop various growth projections in consultation with the Town's staff.
5. Summarize water demand over the past decade to characterize water use patterns and trends and to develop criteria for future water demand.
6. Outline the average-year and dry-year yields of the Town's current water rights portfolio and incorporate near-term water rights additions.
7. Determine the maximum number of SFEs that can be served with the current water rights portfolio and potential timing based on various growth projections.
8. Review existing and proposed infrastructure capacity and constraints.
9. Provide recommendations on how the Town can better meet future water demand with consideration of infrastructure based on current growth projections.

The Town has experienced a high level of growth during the last four to five years due in part to second-home owners. The Town's location at the confluence of Cottonwood Creek and the Arkansas River brings an influx of tourists and recreational enthusiasts. The Town's population can nearly double and create periods of peak water demand, which need to be considered in the development of water demand criteria.

The Town continues to plan for the future to provide a legal, reliable, safe, and sufficient water supply to its customers. Population growth, development of water rights by other water users, and water administrative changes can impact the availability and use of the current water resources portfolio. In particular, the UAWCD on Cottonwood Creek, and large utilities like Aurora, Colorado Springs, and Pueblo Water that have water rights on the Arkansas River, all affect the Town's future water development options. Climate change also poses planning challenges, as its impacts and extremes are uncertain, and will be discussed in this report.

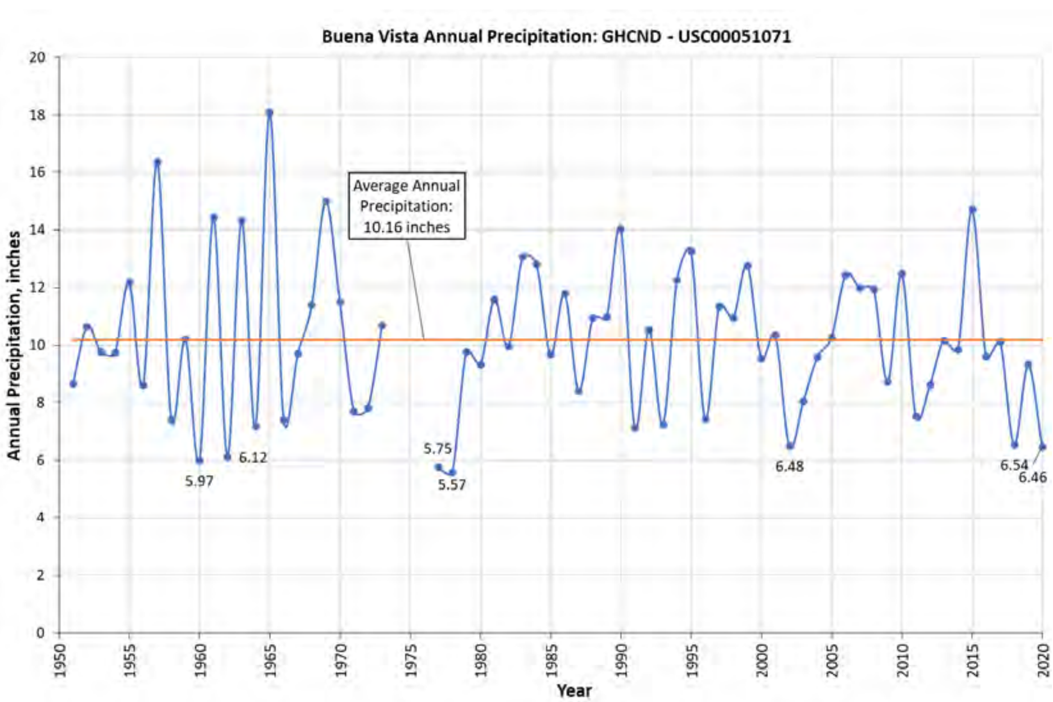
1.2 Hydrology

The physical availability of water is dependent on many factors but primarily is dependent on precipitation and temperature which in turn affect streamflow and demand for water. Municipal water providers are focused on providing a reliable, or firm, water supply not in just average years, but in dry-years. For this reason, it is important to understand both average-year and dry-year climatic and streamflow conditions.

1.2.1 *Precipitation*

Buena Vista's average annual precipitation for the period of 1950 through 2020, as measured at the Airport climate station, is shown on Figure 1. The average annual precipitation for the period is 10.16 inches, shown by the red line. The lowest annual precipitation was 5.57 inches in 1978, which was preceded by the dry-year 1977 with 5.75 inches of precipitation. The precipitation in two recent dry-years was 6.54 inches in 2018 and 6.46 inches in 2020. Over the 70-year period, the precipitation trend shows a decline of approximately 0.5 inches. The variability in precipitation demonstrates the need for a robust water resources portfolio that can deliver a reliable raw water supply in dry-year scenarios.

Figure 1. Buena Vista Annual Precipitation 1950–2020



1.2.2 *Streamflow*

There are two stream gage[1] locations on Cottonwood Creek: Cottonwood Creek below the Hot Springs (referred to herein as the Upper Cottonwood Creek gage) and the Cottonwood Creek near Buena Vista gage (referred to herein as the Lower Cottonwood Creek gage) as shown on Figure 2.

There are records from the USGS stream gage (Station 07089000) for the Upper Cottonwood Creek gage beginning in 1911 and discontinued in 1986. This stream gage, with a contributing drainage area of 65 square miles, is downstream of the confluence of South Cottonwood Creek and Middle Cottonwood Creek and is upstream of North Cottonwood Creek. There are minor irrigation diversions upstream of the gage along with Cottonwood Lake on South Cottonwood Creek and Rainbow Lake on the Middle Fork of Cottonwood Creek. UAWCD installed a gage at approximately the same location as the USGS gage and streamflow records are available for most months for 2012 through 2020.

North Cottonwood Creek has a drainage area of 25.9 square miles. There are several water rights that divert from North Cottonwood Creek including the Gorrel Ditch.

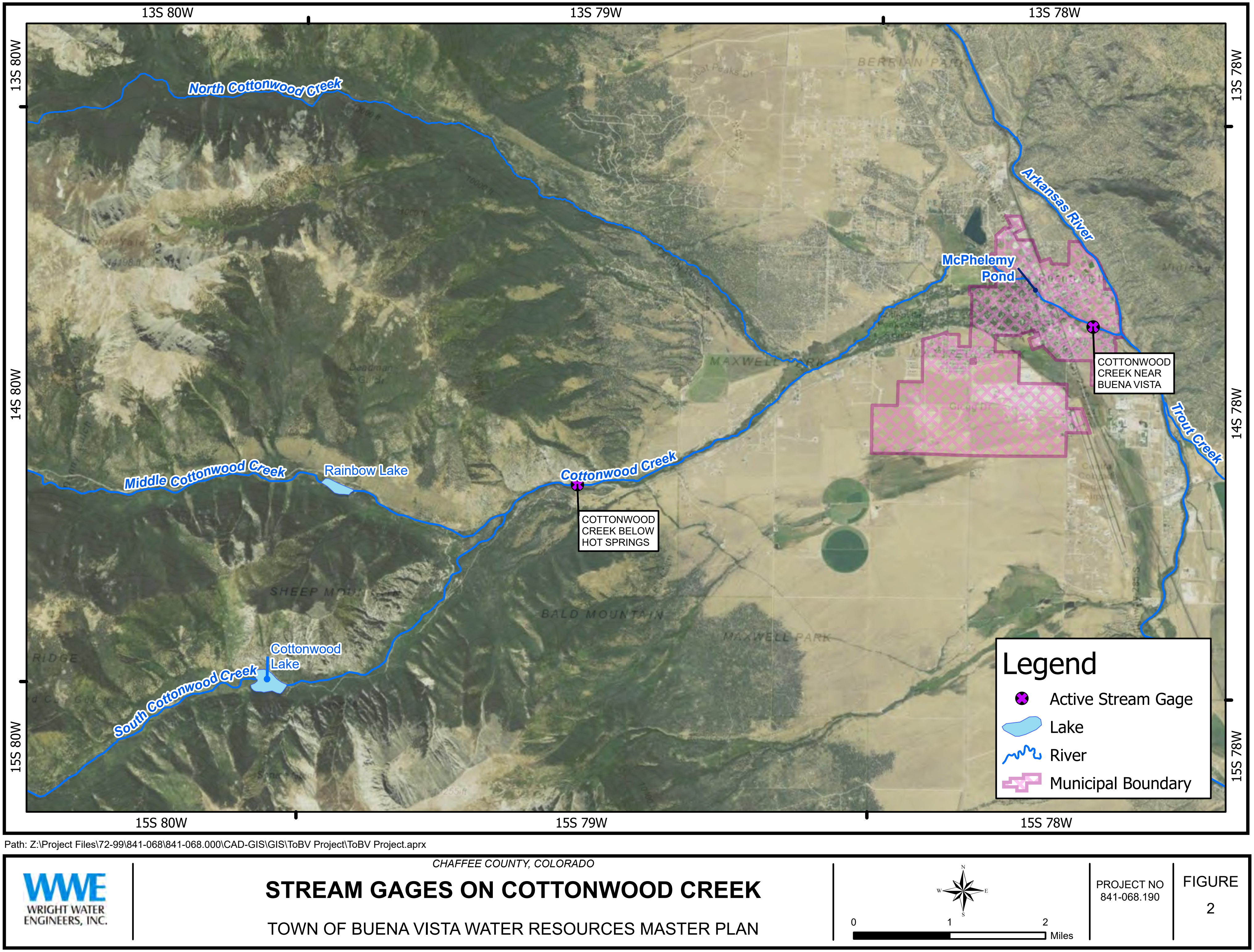
The Lower Cottonwood Creek stream gage is located north of the Buena Vista High School, just below the Trout Creek Ditch diversion headgate and about 0.3 mile above the confluence with the Arkansas River. This stream gage is used to administer many Cottonwood Creek water rights, in particular, the St. Charles Mesa Cottonwood Irrigating 2 water right and the Colorado Water Conservation Board (CWCB) instream flow water rights.

The CWCB instream flow rights include a 20 cfs right on Cottonwood Creek above the confluence with the Arkansas River (the Lower Cottonwood Creek gage is in this reach). The Town, along with joint applicants in a decree, UAWCD and the Southeastern Colorado Water Conservancy District (Southeastern), can divert water dropping the instream flow down to 10 cfs for a period of two weeks, and then the instream flow reverts back to 20 cfs for a week before repeating the cycle.

Other instream flow rights include 10 cfs instream rights on both the Middle and South Cottonwood Creeks and a 7 cfs right on North Cottonwood Creek.

Instream flow water rights, while junior in nature, can impose limitations on development of Cottonwood Creek water supplies by the Town when water rights are changed and for exchanges of water to upstream locations.

[1] Gage, rather than gauge, is the preferred spelling for stream gage stations and is the spelling used by the U.S. Department of Interior Bureau of Reclamation in the *Water Measurement Manual*.



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WWE WRIGHT WATER ENGINEERS, INC.

CHAFFEE COUNTY, COLORADO

STREAM GAGES ON COTTONWOOD CREEK

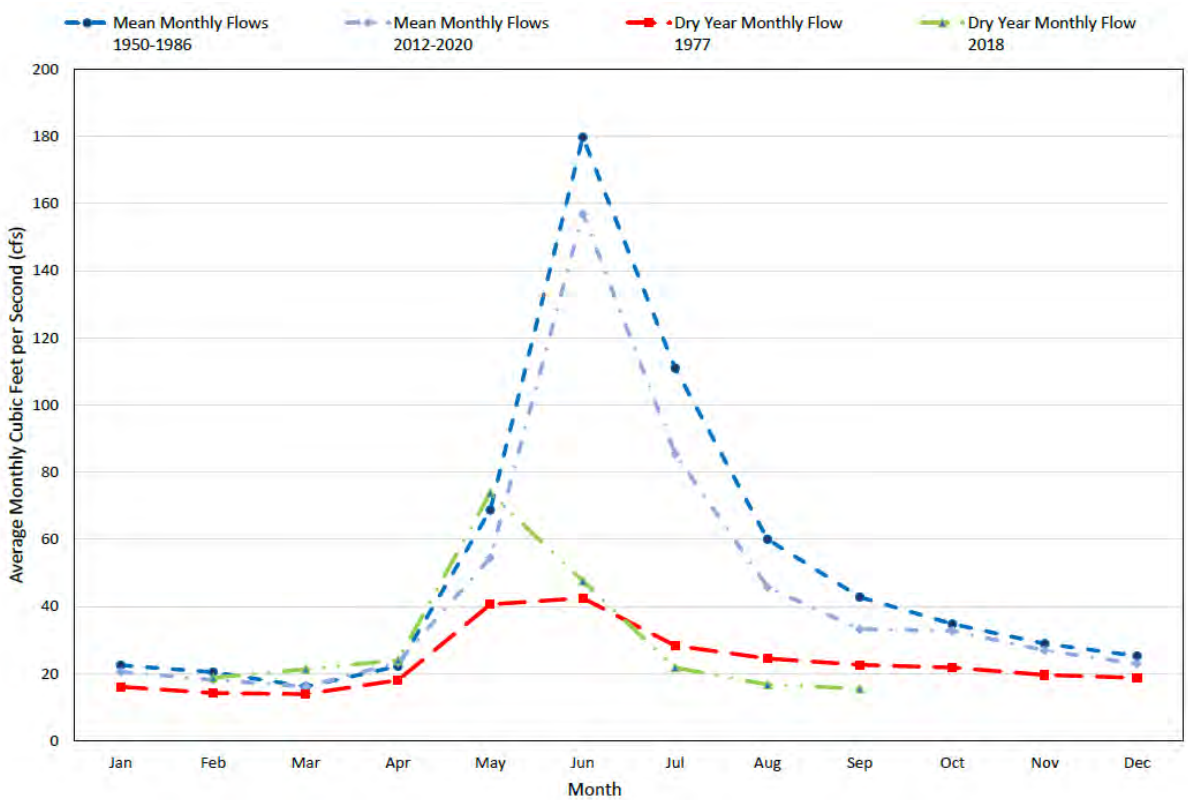
TOWN OF BUENA VISTA WATER RESOURCES MASTER PLAN

PROJECT NO 841-068.190

FIGURE 2

Figure 3 provides a comparison of average monthly streamflow in cfs for the Upper Cottonwood Creek gage for two time periods, 1950–1986 (37 years) and 2012–2020 (9 years). It is important to note that the Town does not have a storage water right or a water storage vessel to capitalize on periods of high runoff.

Figure 3. Streamflow Comparisons—Upper Cottonwood Creek



The average peak flow month is June, and the more recent gage record (2012–2020) shows a mean peak month flow of 157 cfs versus the 180 cfs in the earlier period (1950–1986). The average annual streamflow for the 2012 through 2020 period was approximately 85 percent of the average annual streamflow for the 1950 through 1986 period.

It is important to note the extreme variability of flows between an average year and a dry-year.

Figure 4 shows the Lower Cottonwood Creek gage mean monthly flows for the average of years 1971 to 2020 and the specific dry-years of 1977 and 2018. The mean streamflow in June in the 2012 to 2020 period of record is higher in the month of June but is similar to or lower than the 1971 to 2020 mean streamflow in all other months.

Figure 4. Streamflow Comparisons—Lower Cottonwood Creek

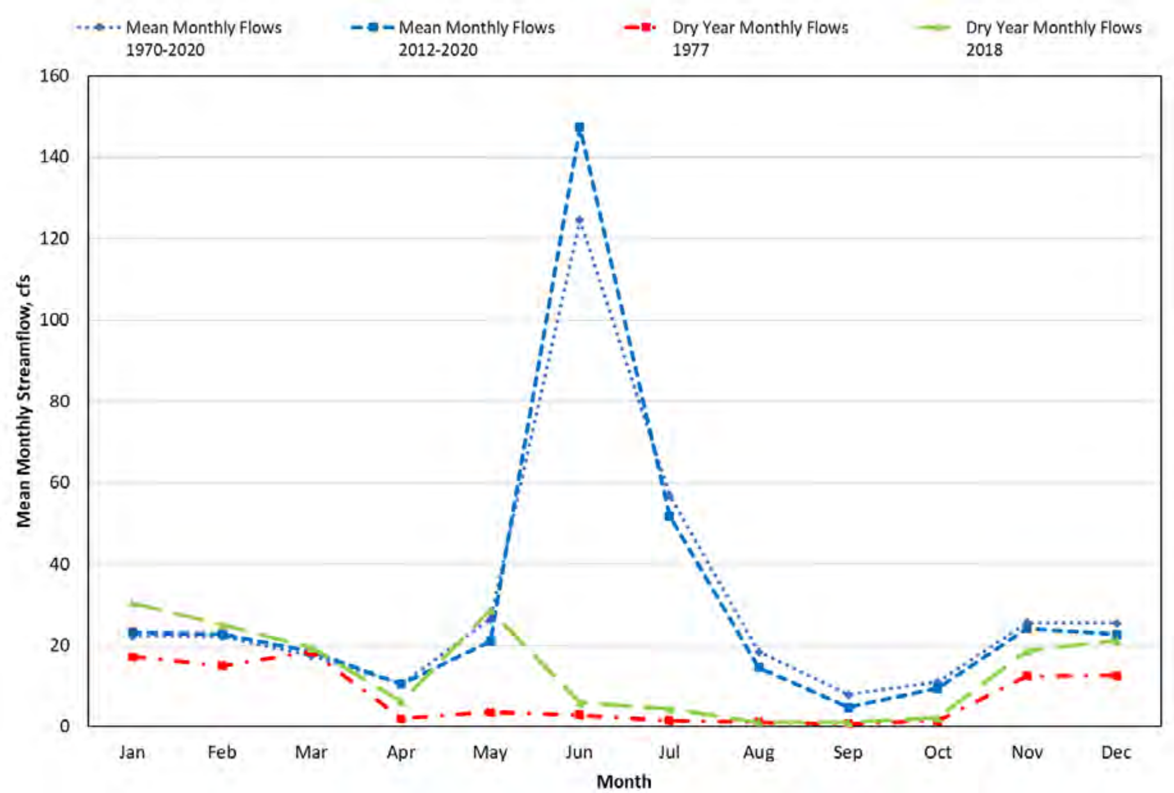
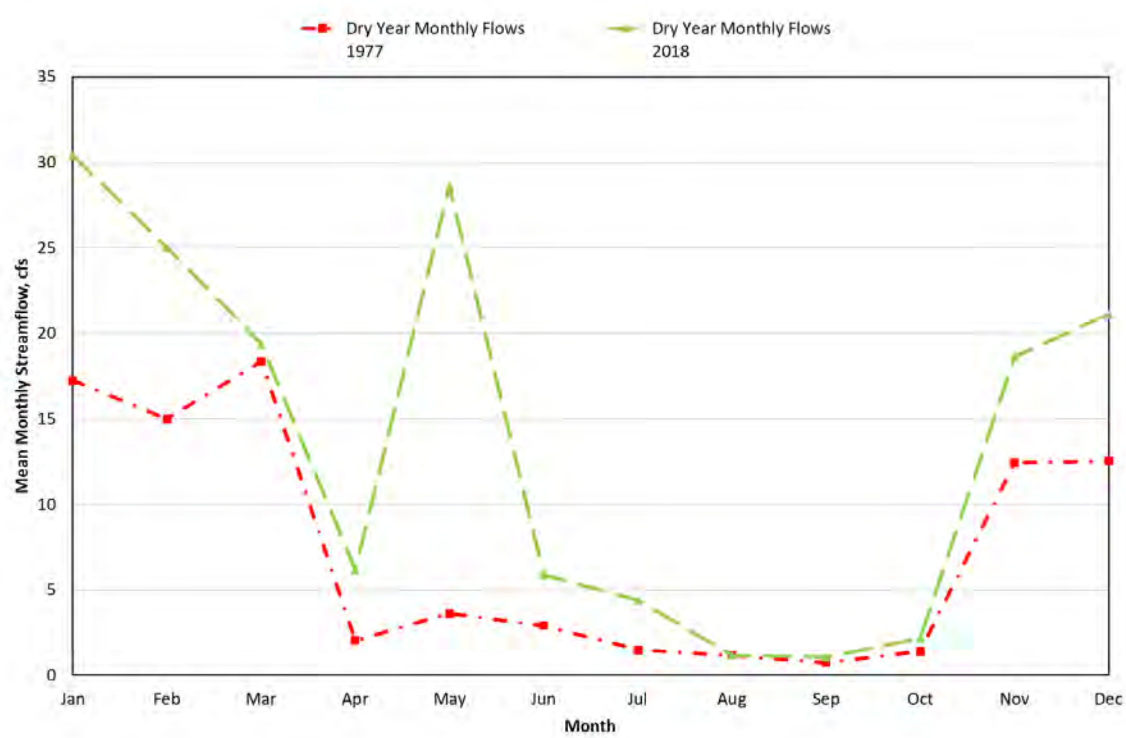


Figure 5 shows the dry-years 1977 and 2018 streamflow at a larger scale. The July 1977 mean streamflow was 1.5 cfs and declined to 0.7 cfs in September. Administration of the CWCB instream flow right can preclude exchange of water upstream on Cottonwood Creek.

The low flows can also trigger subordination of a portion of the Town's water rights to support Lower Cottonwood Creek gage streamflow of 1.2 to 3.8 cfs, the amount dependent on the water available upstream for the St. Charles Mesa Cottonwood Irrigating 2 water right.

Figure 5. Dry-Year Streamflow—Lower Cottonwood Creek



1.2.3 *Climate Change*

The State of Colorado takes a proactive approach to planning for the impacts caused by climate change. The CWCB has been actively evaluating and providing resources to Coloradans since the mid-2000s. Through this effort, the state provides a variety of resources to help communities plan for drought, adapt to climate change, and utilize the latest information when making decisions.

Currently CWCB is working on the Technical Update to the *Colorado Water Plan*. As part of this update, each River Basin is considering the impacts of climate change to water resources. These analyses are built off the Colorado Climate Plan published in 2018. In addition, CWCB completed the *Colorado River Water Availability Study Phase II* (Colorado River Study) in 2019 with key observations summarized as follows:

- Snowmelt occurs earlier, which results in a shift in peak streamflow from June to May with increased streamflow in May and decreased streamflow in June and July.

- The earlier runoff means less natural streamflow available to meet peak irrigation demand typically occurring in June, July, and August.

- The frequency and duration of droughts will increase, that is, droughts will occur more often and extend for longer periods due to multi-year below-average precipitation.

- By the year 2050, crop irrigation demand is projected to increase from 18 to 26 percent above the historical basin demand of years 1950-2013.

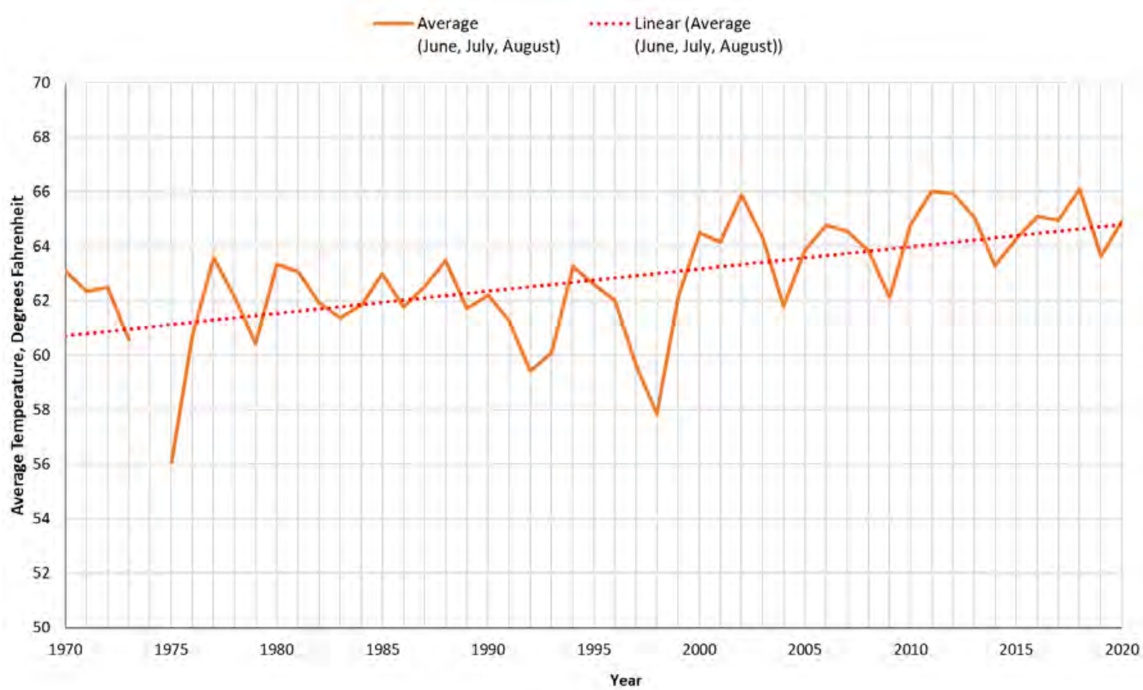
- The model does not address increased demands of the Arkansas or South Platte Basins.

- The study did not include modeling of a Colorado River Compact curtailment. However, the study did note that generally there would not be enough natural streamflow to meet the more junior transbasin diversions. Hence, curtailments from a Compact Call could impact Fry-Ark Project Water from transmountain water supplies.

Although the full suite of models has not yet been performed for other river basins in the State, the Colorado River Study does provide projections of natural streamflow changes for each basin. For the “Arkansas River near Leadville” stream gage station, the mid-range scenario projects a natural streamflow decrease of 3 percent by 2050 while under the more severe “Hot and Dry” scenario, the annual natural streamflow could decrease by 12 percent. Regardless, as temperatures and population increase, it is expected that competition for water in Division 2 will continue to increase.

Changes in climate have already been felt in the Town over the last fifty years. Figure 6 shows the average irrigation season temperature from 1970 to 2020 at the Buena Vista Airport Climate Station (GHCN–USC0051071), which has a distinct upward trend and an average temperature increase of about 1.8 degrees Fahrenheit.

Figure 6. Average Irrigation Season (June, July, August) Temperature at Buena Vista Airport



1.2.4 *Wildfire*

The potential for more intense droughts creates a higher risk for fires in the watershed which can lead to impacts to both the source of water supply as well as existing infrastructure. A forest fire can detrimentally impact drinking water sources for years. Initially, post-fire soils runoff can cause increased turbidity and nutrient loading, as well as taste and odor issues. Wildfire was listed as one of the most prevalent and most threatening hazards for the Town of Buena Vista in the 2016 RG *Town of Buena Vista Source Water Protection Plan* (SWPP). The report provides best management practices (BMPs) for the Town to prepare for wildfire.

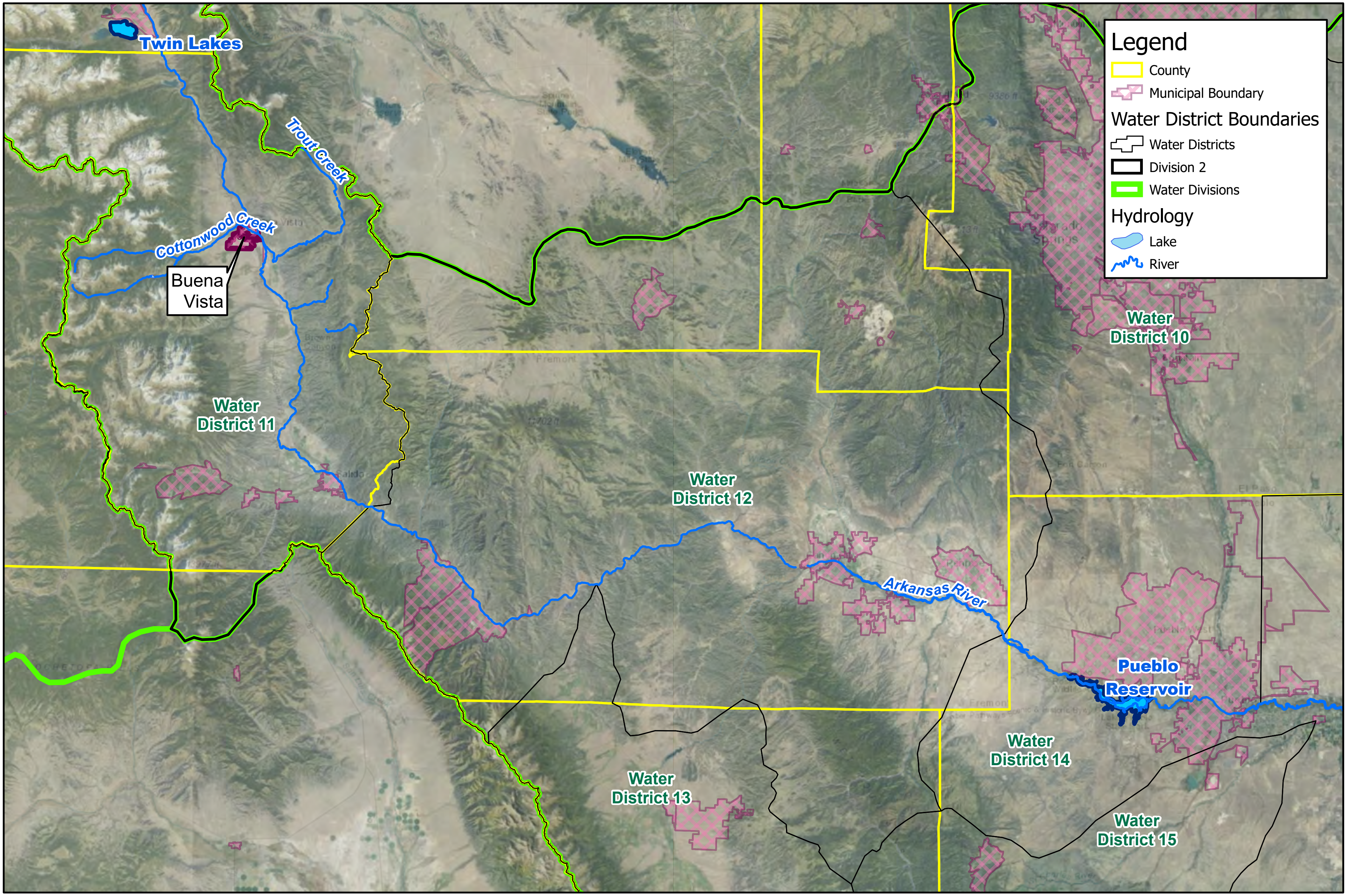
In the event of a wildfire, the Infiltration Gallery may provide a buffer from many of the high sediment loads often seen in the initial post-fire precipitation events. However, constant monitoring of the incoming gallery water will need to be performed to continue operation and assess the existing risk from the fire events. The Town should continue to implement strategies identified by the SWPP and work with the USFS to continue to evaluate other preventative and mitigation strategies.

1.3 Town of Buena Vista Water Supply System

The Town of Buena Vista is in the Arkansas River Water Division 2, Water District No. 11 (Upper Arkansas) as shown on Figure 7. Upstream and downstream water users and future development can have an impact on current and future water operations, which will be addressed in this Plan. Source water diversions are available through groundwater collection, well withdrawals, and direct diversions off Cottonwood Creek.

The foundation of the Buena Vista water supply is its senior Cottonwood Creek water rights, which can be diverted through the Infiltration Gallery underlying the Gorrel Meadow or from direct surface water diversions from Cottonwood Creek. Fry-Ark Project Water has been purchased and is managed through releases from water stored in Fry-Ark Project facilities through deliveries by Southeastern to the confluence of Cottonwood Creek and the Arkansas River. Additionally, the Town recently purchased an Arkansas Basin irrigation water right (Dryfield Ditch) in 2021 and continues to research other water right opportunities, including the construction of a second Arkansas well (Well No. 4).

Figure 8 is a "straight line diagram," which is a simplistic sketch to show the relative location of water right structures on a portion of Cottonwood Creek and on the North Fork of Cottonwood Creek. There are additional junior rights and water storage vessels that have little or no impact on the Town's water rights and they are not shown on this diagram. Along with the water right structure name is the appropriation date and the decree amount in cfs. The water rights of the Town are shown in red.



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WWE WRIGHT WATER ENGINEERS, INC.

CHAFFEE COUNTY, LAKE COUNTY, FREMONT COUNTY, PARK COUNTY, TELLER COUNTY, CUSTER COUNTY, PUEBLO COUNTY, EL PASO COUNTY, AND SAGUACHE COUNTY, COLORADO

WATER NEIGHBORHOOD

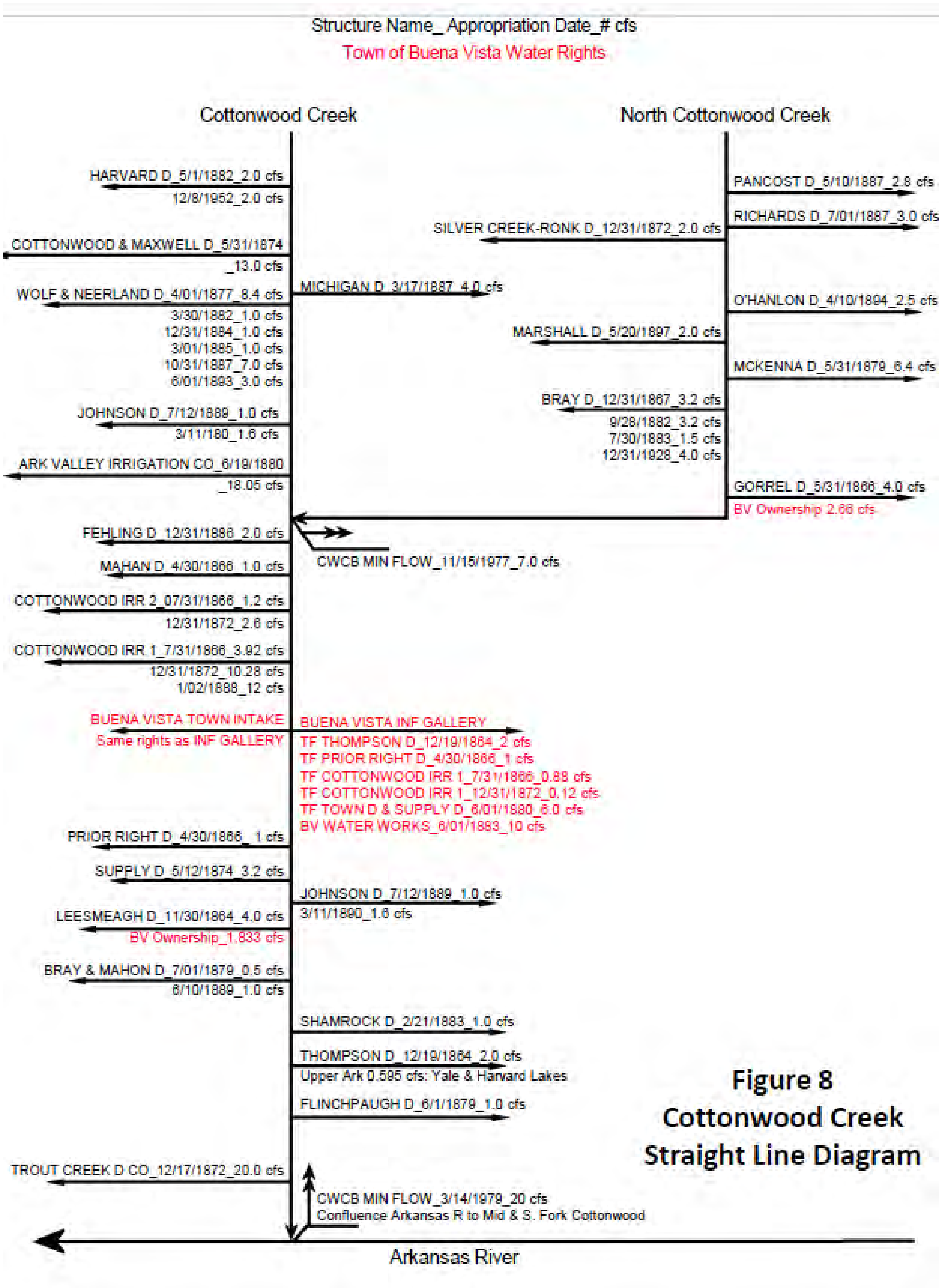
BUENA VISTA WATER RIGHTS MASTER PLAN

0 7 14 Miles

PROJECT NO 841-068.190

FIGURE 7

Figure 8. Cottonwood Creek Straight Line Diagram



1.4 Source Water Protection Plan

Source water protection is important in reducing the risk of contaminating the source water supply. The contamination of a source water supply can lead to additional treatment costs or even a temporary or long-term prohibition from using the contaminated source water, which could have a major impact on the Town's ability to provide potable water to the community. Contamination can be in the form of biological, chemical, or sediment run-off from fire events.

Source water protection is crucial to the reliability of a water supply. The Town developed a Source Water Protection Plan (SWPP) in 2016 to minimize the potential financial and water supply risks related to water contamination. A copy of the SWPP can be found on the Town's homepage at https://www.buenavistaco.gov/2194/Master-Plans. The basics of the Town's SWPP include:

- Establishment of best management practices (BMPs) to protect source water.
- Determination of boundaries for the source water protection area.
- Prioritization of the water sources and potential contaminant sources to determine the best source water protection measures on which to focus. Through this process, water sources were evaluated based on the source water total susceptibility and/or physical vulnerability scores, while potential contaminant sources were evaluated based on prevalence, potential threat to contaminate, and proximity to and influence on the source water.

The following focus areas were identified:

- The SWPP recommended that source water protection measures should focus on the Cottonwood Creek drainages.
- The SWPP identified commercial wastewater systems, septic adsorption fields, and USFS activities as the "most prevalent and threatening" discrete contaminant sources.
- The SWPP identified stormwater erosion, recreational uses, insect infestations, and wildfire impacts as the "most prevalent and threatening" dispersed contaminant sources.
- The SWPP noted that public participation is fundamental to the success of the SWPP and that the Town, or an established and respected local interest group, should take the lead in organizing the protection planning efforts.

The greatest impacts to the Town's available water supply would occur if the Cottonwood Creek drainages were contaminated. Engaging the local community around SWPP measures typically brings additional awareness and ownership around general conservation or the need to respond to extraordinary events (e.g., droughts, regulatory changes, fires, etc.) that can impact the Town's water supply. Hence, continued education and engagement are both recommended and expected to yield positive results.

2.0 DEMOGRAPHICS

2.1 Population and Water Service Connections History

Table 1 provides the population from the State Demography Office over the past nine years for Chaffee County and Buena Vista with an average annual growth rate of 1.18 percent for the Town. Because the State Demography Office population figures for Buena Vista do not capture the impact of the tourist and second-home growth in the Town, the SFE count is more informative.

The SFE method is a means to define the water or sewer service demand that will be experienced from a single-family household. Because the Town has a mix of uses including apartments, public services (e.g., schools and libraries), retail, and office space, etc., a conversion schedule is applied to determine an equivalent SFE for planning purposes. The applied SFE numbers for the Town were taken from published Town SFE numbers and reported SFE annual growth numbers provided by Town staff. Table 1 indicates the historic SFEs by year with 1,810 SFEs in early 2021.

Table 1. Historic Buena Vista Population and SFEs

Year	Population[1]		Buena Vista SFEs[2]	New SFEs During Year[3]
	Chaffee County	Buena Vista		
2010	17,797	2,615		
2011	18,031	2,642		
2012	18,164	2,661		
2013	18,330	2,724	1466	
2014	18,462	2,733	1476	10
2015	18,604	2,756	1486	10
2016	19,116	2,796	1527	41
2017 [2]	19,661	2,847	1575	48
2018	20,063	2,876	1654	79
2019	20,361	2,906	1736	82
2020			1810	74
% Change 2010—2019	1.51%	1.18%	3.06%	

[1] State Demography Office

[2] The *Public Works 2017 SFE Count* included 1,223 SFEs in Lower Pressure Zone and 351 SFEs in Upper Pressure Zone for a total of 1,574 SFEs (rounded to 1575). SFEs for other years are calculated based on new SFEs during the year.

[3] The SFEs added are from *Town Development Trends* 2016—2019

Current trends may not be indicative of future trends. Hence, several growth scenarios are evaluated based on input from Town staff to provide a range of estimated projections for total SFEs through 2060. Table 2 shows these projected SFEs for 1) a 1.3 percent SFE growth rate as used in the *Town 2015 Comprehensive Plan*, 2) a 50 per year SFE growth rate as an approximate average of the actual SFE growth rate from 2014 through 2020, and 3) a 70 per year SFE growth rate that would be considered on the high end for an extended period of time but is near the average for the last several years. For the growth rates analyzed, the year 2060 projected population could range between 4,900 and 8,300.

Table 2. Projected SFE Growth

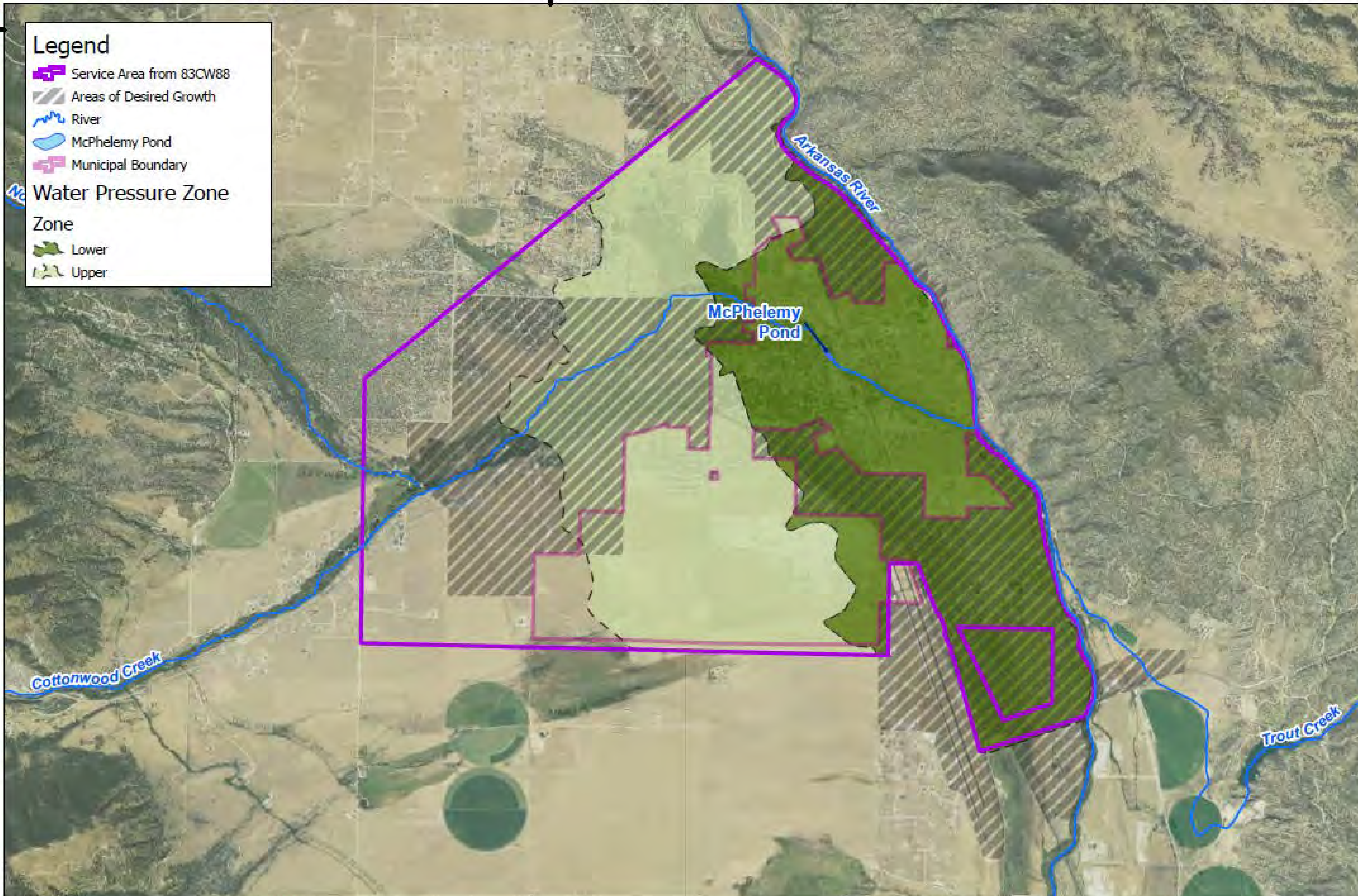
Year	Total Projected SFEs		
	1.3% annual increase	50 SFEs/year	70 SFEs/year
2020	1,810	1,810	1,810
2025	1,931	2,060	2,160
2030	2,060	2,310	2,510
2035	2,197	2,560	2,860
2040	2,344	2,810	3,210
2045	2,500	3,060	3,560
2050	2,667	3,310	3,910
2055	2,845	3,560	4,260
2060	3,035	3,810	4,610
2060 Population Estimates[1]	4,932	6,858	8,298

[1] Based upon 1.8 persons per SFE

2.2 Existing Water Service Areas

There are two service areas shown on Figure 9: 1) the Water Rights Case No. 83CW88 boundary of service for the water rights included in that case, and 2) the infrastructure practicable service area based on the pressure zone boundaries. Note that the 83CW88 boundaries exclude service to the Johnson Village area. The infrastructure practical service area is based largely on the water pressure zone boundaries.

The Town continues to strategically plan to accommodate growth. The factors that most impact the ability to support the growth within the future service areas include the infrastructure used to support the Upper and Lower Zones and the water resources portfolio. It should be noted that potential areas of future growth that extend beyond the Case 83CW88 boundary will require additional water rights.



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WRIGHT WATER ENGINEERS, INC.

CHAFFEE COUNTY, COLORADO

FUTURE GROWTH AREAS

TOWN OF BUENA VISTA WATER RESOURCES MASTER PLAN

0 0.5 1 Miles

PROJECT NO 841-068.190

FIGURE 9

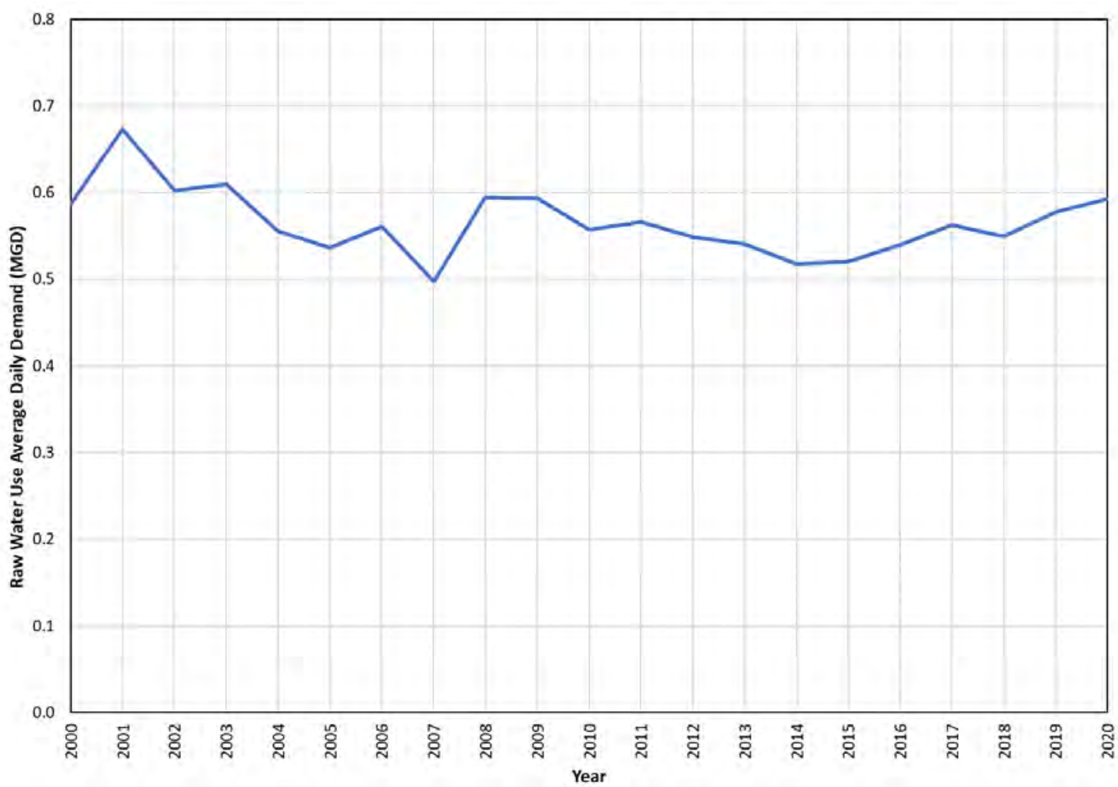
3.0 WATER DEMAND

Water demand for the Town has fluctuated over the years with impacts from seasonal residents, second-home owners, and the installation of water meters in 1998 that appeared to increase awareness, resulting in some water use reductions. Historic demand, type of water user, and unaccounted water have an impact on both the planning for future water use as well as providing a reasonable estimate of water use per SFE. The following sections provide background on the historic water use, and projected future use, and focus on the raw water demand of the system (direct surface or groundwater diversions) versus treated and metered water that is delivered to the customers of the Town. In so doing, the direct impacts of water demand placed on the water rights portfolio can be evaluated.

3.1 Historic Water Use

The average daily raw water demand in MGD for years 2000 through 2020 is shown on Figure 10. The average daily water use declined from a high in 2001 despite growth as shown in Table 1 (page 17), and since 2008 has ranged between 0.5 and 0.6 MGD. The annual maximum daily demand (MDD) has ranged between 1.3 and 1.49 MGD in years 2014 through 2020.

Figure 10. Average Annual Raw Water Diversions 2000–2020



The demands placed on the system are comprised of typical municipal uses including residential, commercial, industrial, and recreational uses as illustrated on Figure 11. Historic demand has been reported at 293 gallons per day (gpd)/SFE based on metered water use and 400 gpd/per residence for raw water demand from the 2006 Schmueser Gordon Meyer (SGM) report. Table 3 provides the gpd/SFE numbers based on raw water and metered water demand from the years of 2015 through 2020. Calculation projections herein are based upon a raw water demand of 350 gpd/SFE. Current water demand over a typical year will vary based on seasonal population changes as well as more efficient water use and conservation that may occur through voluntary or administered methods. The MDD for the months of April through October ranged from 1.07 to 2.31 cfs (0.69 to 1.49 MGD) based on raw water records submitted to the State for years 2013 through 2020. The monthly MDDs are used in the detailed analysis provided in Section 4.3 that will estimate the maximum SFEs that can be supported with the current water resources portfolio in average and dry-years.

Table 3. Calculated Water Demand per Single Family Equivalent

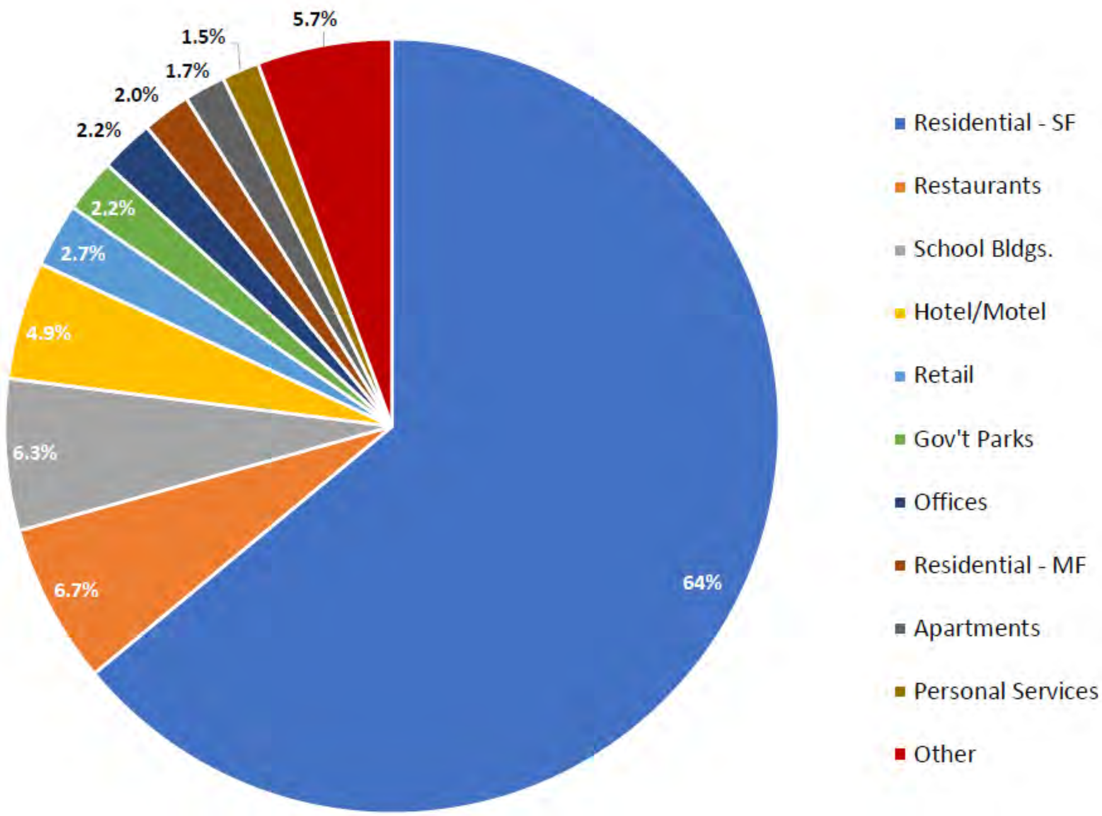
Year	SFE	Raw Water[1]	Metered Water[2]
		(gpd/SFE)	
2015	1486	349	272
2016	1527	362	283
2017	1575	362	266
2018	1654	349	274
2019	1736	333	235
2020	1810	329	255
Average		347	264

[1] Raw Water Diverted

[2] Metered Water Recorded from Annual Consumption Summary Reports

Figure 11 shows the Town's metered water use by category. The figure demonstrates what is generally found within a municipal community related to a higher level of residential users followed by restaurants, public buildings, hotels, and retail. A knowledge of the water users can help with future conservation and water demand studies.

Figure 11. Town Metered Water Use by Category 2018–2020



3.1.1 *Unaccounted (non-revenue) Water*

Unaccounted water, or non-revenue water, has both financial and planning impacts. The Town derives no income from non-revenue water, and non-revenue water is a demand on the water supplies and infrastructure that is not included in metered demand. Identifying contributors to the high unaccounted water numbers can help the Town reduce the amount of non-revenue water by 1) charging users who should be paying for non-revenue water, such as from hydrants or from unauthorized taps; 2) identifying and repairing sources of loss such as leaks; and 3) replacing aging water distribution system piping.

Table 4 shows the annual raw water diversions and the metered water deliveries in units of acre-feet (AF) and MG with the difference being the unaccounted water loss. The unaccounted water has been as high as 30 percent (2019), while averaging 24 percent for the years 2015 through 2020. Identifying the contributors to the high unaccounted water numbers can provide additional revenue as well as potentially identifying water that may be lost or wasted that could be used to support future growth projections.

Table 4. Unaccounted Water Percentage Loss

Year	Acre-Feet (AF) per Year			Million Gallons (MG) per Year			% Loss
	Raw Water[1]	Metered Water[2]	Loss	Raw Water[1]	Metered Water[2]	Loss	
2015	581	452	129	189	147	42	22
2016	620	484	136	202	158	44	22
2017	639	469	170	208	153	55	27
2018	647	507	139	211	165	45	22
2019	648	457	191	211	149	62	30
2020	666	518	148	217	169	48	22
Average	634	481	152	206	157	50	24%

[1] Raw Water Diversions

[2] Metered Water Recorded from Annual Consumption Summary Reports

3.1.2 *Fire Flow Demand and Water Storage*

The potable water storage should be sized to supply the maximum-day demand and the fire flow. The maximum-day demand in the summer is approximately 1.5 MG with an estimated 80 percent of the demand occurring in the Lower Zone for a 1.2 MG demand. The maximum fire flow requirement is 3,500 gpm for three hours or 0.63 MG for a total storage requirement of 1.83 MG for the Lower Zone. The water storage volume available to the Lower Zone totals 2.46 MG (1.76 MG in Lower Zone + 0.63 MG from the Upper Zone) and therefore, the Lower Zone water storage volume is sufficient.

The Upper Zone storage volume is 1.5 MG. Deducting a fire flow demand of 0.63 MG leaves a volume of 0.87 MG for the Upper Zone maximum-day demand. In 2017, there were 351 SFEs in the Upper Zone which would have a maximum-day demand of 830 gpd per SFE or 0.29 MG as compared to the 0.87 MG available.

Tracking of the SFEs by pressure zone is valuable information for continued review of the water storage capacity.

3.1.3 *Water Conservation and Efficiency Improvements*

Water conservation and efficiency improvements can be implemented by technical or behavioral initiatives. The opportunity to support future growth through water conservation, either through continuous conservation improvements or during specific dry-year initiatives and restrictions, is highlighted in Section 4.3, where a 20 percent reduction in water demand during a dry-year translates to a similar level of SFE growth support that can provide the Town with a significant buffer for future growth.

Though commercial uses (retail, public facilities and parks, and hotel/motels) only encompass about 23 percent of the total water demand (Figure 11, page 22), it is also important to leverage conservation within both the existing and new construction. These industries can champion the benefits of conservation to their customers, especially through low-water-use landscaping practices, and play a major role in participating in local SWPPs.

Technical initiatives would focus on design standards or guidelines relative to current and future development. Behavioral initiatives are typically driven through educational processes on the importance of managing indoor and outdoor water use to influence water user decisions and efforts. A few examples for each of these initiatives include:

- Review of the Environmental Protection Agency (EPA) WaterSense Program to consider items that might make sense for the Town to effectively incorporate into any local project or program.

- Design standards and/or guidelines for new construction including residential, commercial, and industrial buildings with a focus on low-water-use fixtures and appliances as well as outdoor landscaping.

- Maximum allowable “green” area coverage with grass or plantings that require supplemental irrigation. As some of the sites can encompass one acre or more within the Town, it is recommended that this be applied to a set area versus a percentage of a “lot.”

- Provision of educational materials on low-water-use plants, trees, and ornamentals as well as native species that are acceptable to the Town.

- Provision of educational materials on irrigation technologies that can help reduce water, such as mechanical techniques (e.g., drip irrigation) or soil moisture monitoring.

- Provision of design and educational materials that provide recommendations on the replacement of existing or broken appliances or plumbing fixtures with low-flow alternatives.

- Recommendations on home winterization techniques that avoid or minimize the practice of homeowners leaving the taps on at a drip during the winter months to avoid freezing pipes.

- Clear communications that provide Best Practices during average years as well as what Voluntary Restrictions or Required Restrictions might look like during dry-years. Allowing the community to understand the “what, why, and when” of restrictions can be imperative to the success of these initiatives.

- Enforcement actions that may need to be instituted in times of drought or system maintenance. Enforcement could be in the form of verbal or written warnings, fines, and even water shut-off. The Town should determine what would be the most effective approach for their community based on prior experiences and engagement.

It is recommended that the Town create a more formal program to address future conservation, as the above are just some high-level examples of areas that may provide direct benefit by extending the current water supply to meet future growth.

4.0 TOWN OF BUENA VISTA PORTFOLIO OF WATER RIGHTS

4.1 Town's Existing Water Rights

The Town's water rights ownership and key parameters are summarized in Table 5 and consist of water that is either diverted from a surface stream or pumped from a groundwater source. The water rights with the adjudication date of June 19, 1890, and the 1860s appropriation dates are the Town's senior irrigation season rights and are on Cottonwood Creek. In the non-irrigation season, the Buena Vista Water Works 1880 water right is the senior water right on Cottonwood Creek. The senior irrigation season water rights may currently be diverted either through the Infiltration Gallery underlying the Gorrel Meadow or through the Town Intake to the WTP. The general locations of the structures associated with these water rights are shown on Figure 12. For additional reference, see Figure 8, Straight Line Diagram (page 15).

Table 5. Town of Buena Vista Water Rights

WDID	Structure Name	Adjudication Date	Appropriation Date	Priority Admin No.	Amount		Associated Case Numbers	Decreed Use(s)
1100935	BUENA VISTA INF GALLERY						83CW88	
1100934	BUENA VISTA TOWN INTAKE							
110935 & 110934	LEESMEAGH DITCH	6/19/1890	11/30/1864	5448.0	1.833 [1]	cfs		Irrigation, Municipal, Recreation, Fire, & Domestic
	THOMPSON DITCH	6/19/1890	12/19/1864	5467.0	2.0	cfs		
	PRIOR RIGHT DITCH	6/19/1890	4/30/1866	5964.0	1.0	cfs		
	GORREL DITCH	6/19/1890	5/31/1866	5995.0	2.66 [2]	cfs		
	COTTONWOOD IRRIGATING #15	6/19/1890	7/31/1866	6056.0	0.88 [3]	cfs		
	COTTONWOOD IRRIGATING #43	6/19/1890	12/31/1872	8401.0	0.12 [3]	cfs		
	BUENA VISTA WATER WORKS	9/10/1904	6/1/1883	11110.0	10.0	cfs		Municipal & Domestic
	TOWN DITCH (& Case 89CW0029)	7/14/1903	6/1/1880	11110.0	4.0	cfs		Irr, Mun., Rec, Fire, & Domestic
	SUPPLY DITCH	7/14/1903	6/1/1880	11110.0	2.0	cfs		
1105793	BUENA VISTA WELL NO 1	9/10/1904	6/1/1880	11110.0	0.1	cfs		
1105794	BUENA VISTA WELL NO. 2	12/31/1998	2/10/1939	32547.0	0.334	cfs	98CW38	Above + Comm. & Ind.
		12/31/1998	2/10/1939	54056.3	0.254	cfs exchange	19CW3074, 98CW38	Municipal
110935 & 110934	BV CONTRACT EXCHANGE OF FRY-ARK WATER	12/31/1996	2/12/1996	53368.0	10.0	cfs	96CW17	Municipal
					75	AF		
1103558	MCPHELEMY POND	12/31/2016	3/24/1905	60630.2	4.16 [4]	AF	16CW3101 & 17CW3072	Recreation & Fishery
1100538	DRYFIELD DITCH	6/19/1890	10/23/1882	11984.0	3.1	cfs	CA1127	Irrigation

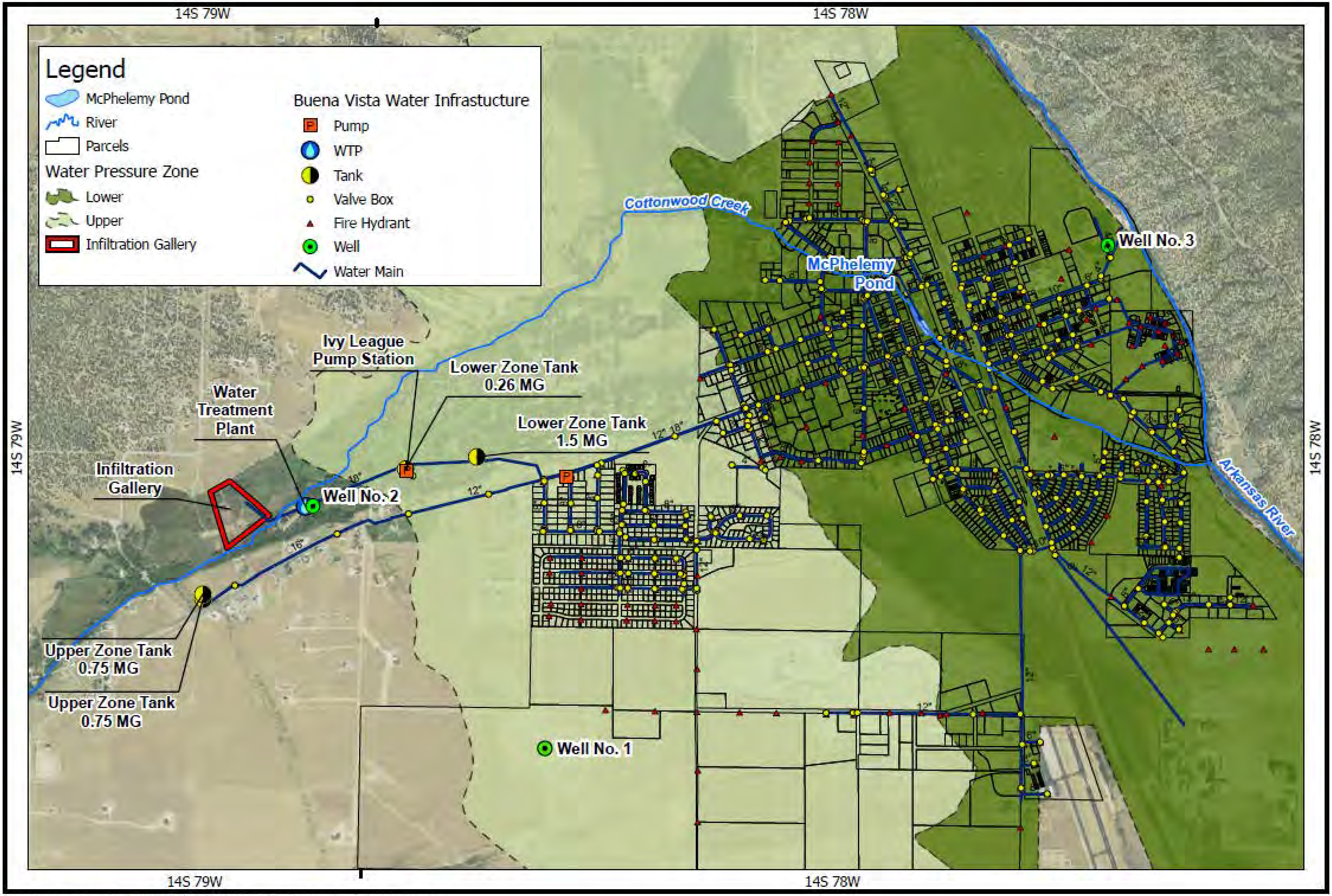
[1] Dry up of 63 acres required before use at infiltration gallery or intake and monthly flow limits apply

[2] Dry up of 48 acres required before use at infiltration gallery of intake and monthly limits apply

[3] Subject to limitations when St. Charles Mesa Cottonwood Irrigating water right not satisfied (W-4411).

[4] Absolute right for in-pond uses; One refill annually for total 8.32 AF/Yr

As indicated in Table 5, footnotes 1 and 2, the Gorrel Ditch and Leesmeagh Ditch water rights must meet stringent dry-up requirements before they can be utilized for withdrawals from the Town Infiltration Gallery and Town Intake. Upon successful dry-up, the water rights are limited to use in May through September and are subject to monthly diversion limits. The Gorrel Ditch right is currently used under its 2.66 cfs irrigation right to irrigate the Gorrel Meadow, which enhances the yield of the Infiltration Gallery.



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WWE WRIGHT WATER ENGINEERS, INC.

CHAFFEE COUNTY, COLORADO

WATER INFRASTRUCTURE

TOWN OF BUENA VISTA WATER RESOURCES MASTER PLAN

0 0.25 0.5 Miles

PROJECT NO 841-068.190

FIGURE 12

A basic summary of the Town's water rights follows:

a) The municipal use Buena Vista Water Works right is the senior right on Cottonwood Creek in the non-irrigation season and is a primary source of raw water for the Town.

b) The Town acquired and changed the Cottonwood Irrigating water right and the Prior Right water right to the Town Intake in 1958, in Civil Action 4738. In 1966, the Town acquired and changed the Thompson Ditch to the Town Intake in Civil Action 5512.

c) The Case No. 83CW88 Decree confirmed the character of domestic and municipal use for the previously changed locations of the Thompson Ditch, Cottonwood Irrigating, and Prior Right. The decree outlines conditions for a change of location to the Town Intake and Infiltration Gallery and a change to municipal use for the Leesmeagh and Gorrel water rights. The court decree allows a small portion of the Buena Vista Water Works right to be diverted at the Town Well No. 1. The decree also includes a Water Service area map as shown on Figure 9 (page 19).

d) Buena Vista's Cottonwood Creek water rights, with the exception of the Buena Vista Water Works right, are limited to use in the period from April 1 through October 31.

e) The Town Ditch and the Supply Ditch water rights with 1903 appropriation dates are junior rights and will be out of priority much of the time and do not add to the Town's capability to serve additional SFEs.

f) The Town has purchased Fry-Ark Project Water and currently has approximately 1,000 AF in its account. The Fry-Ark Project includes trans-mountain diversions from the West Slope and water storage in Bureau of Reclamation Facilities near Leadville and in Pueblo Reservoir. Releases can be coordinated to allow exchanges of water to Cottonwood Creek or to provide replacement water for Arkansas well diversions. The Town's Fry-Ark Project Water is subject to evaporation losses, which have averaged approximately 100 AF annually in recent years. An issue the Town will likely face is reduction in the Fry-Ark supplies due to drought conditions on the Colorado River. Despite the future uncertainty of the Fry-Ark yield, the Town should continue to purchase as the water is available.

g) The Town, in a joint application with Southeastern and UAWCD, obtained the Case No. 96CW17 decree that allows the Town to divert by exchange its Fry-Ark Project Water to the Town Intake and Infiltration Gallery and to store up to 75 AF of Project Water each year in Cottonwood Lake (on South Cottonwood Creek) and Rainbow Lake (on Middle Cottonwood Creek) as shown on Figure 2 (page 7). In Case No. 98CW38, the Town obtained a decree approving an exchange of Project Water to Well No. 2 located adjacent to the WTP.

h) In 2018, the Town obtained decrees for McPhelemy Pond, one decree for a junior storage right (Case No. 2016CW3101) and the second decree for a plan for augmentation (Case No. 2017CW3022) that allows the pond to be filled and to retain water during much of the irrigation season. Replacement of the evaporative losses can be made by a release of water from the water allocated to the Town in Cottonwood Lake (up to 10 AF) or a release from McPhelemy Pond itself by removing flash boards to lower the water level. This right allows for multiple uses including municipal and recreational.

i) In 2021, the Town purchased the Dryfield Ditch water right, which diverts from the Arkansas River and historically irrigated the property located approximately 10 miles north of Buena Vista. This right will require a water right change case to utilize the water for future municipal use or for replacements and/or exchanges.

4.2 Water Right Return Flow Estimates

Certain water supply sources such as Fry-Ark Project Water or future water rights changed in Water Court to provide municipal use for the Town provide an opportunity to claim credit for return flows due to the reusable nature of the water diverted into the Town system. Based upon the recent water use patterns of the Town, Table 6 provides an estimate of return flows using an example annual diversion amount of 100 AF. For a 100 AF diversion during the irrigation season, the indoor use return flow from the Buena Vista Sanitation District wastewater treatment plant (WWTP) is estimated to be 59.3 AF per year (the percent return varies and is subject to change). The outdoor use return flow is 5.1 AF per year and is referred to as lawn irrigation return flow or LIRF. The LIRF amount that could be expected would be approximately 5 percent of the annual diversion amount.

Table 6. Return Flow Estimate for 100 AF Diversion

Use	Diversion	Return Flow		Depletion
	AF/Yr	%	AF/Yr	AF/Yr
Indoor	65.9	90.00	59.3	6.6
Outdoor	34.1	15.00	5.1	29.0
Total	100.0	64.4%	64.4	35.6

A LIRF credit is not available from the water rights included in Case 83CW88.

4.3 Maximum Single Family Equivalent Support Levels

It is anticipated that water demand, on a per SFE basis, will remain consistent or decline slightly over time as new design standards and conservation are instituted and applied throughout the Town. As such, a raw water demand of 350 gpd/SFE is used to determine how many SFEs the Town could ultimately support. This analysis focused on water rights being the limiting factor for the Town during a dry-year scenario. It is assumed that infrastructure limitations will be addressed through the Town's capital improvements planning process. The raw water demand should be periodically reviewed to determine if existing development, conservation, or maintenance is impacting the gpd/SFE demand.

Three scenarios, based on water rights yield (infrastructure capacity is discussed in Section 5.0), were considered to determine the maximum supported SFE levels for the Town: the average-year water rights yield, the dry-year water rights yield, and the dry-year water rights yield with conservation practices in place to provide a minimum of a 20 percent reduction in raw water demand.

Note that the Gorrel and Leesmeagh rights are not available for municipal diversions until irrigation dry-up requirements are met. To achieve dry-up, installation and monitoring of piezometers (tubes placed in ground to allow measurement of groundwater depth) will need to demonstrate that depth to groundwater is at least four feet. Efforts to demonstrate dry-up under the Leesmeagh Ditch showed only a small portion of the irrigated area drying up. Future changes in the irrigation patterns and hydrology in the area will likely be required to allow successful dry-up for the Leesmeagh Ditch water right. The Gorrel water right is very valuable as a recharge source for the Infiltration Gallery.

Tables 7, 8, and 9 provide the calculations used to determine the maximum SFEs that can be supported by the Town's existing water rights. For each water right the maximum allowable monthly diversion amount is given, and the total of the rights is compared to the maximum-day demand per month from the 2013—2020 time period. The "future water" included in the following tables includes an estimate for the Dryfield Ditch water that was purchased by the Town in early 2021. The maximum-day demand for the critical months of June and July are 2.31 cfs and 2.15 cfs (1.49 MGD and 1.45 MGD) respectively.

Table 7. Maximum SFE Based on Average-Year for Max Daily Demand

Average-Year Supply	Maximum Allowable Monthly Diversions, cfs						
	Nov- Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Thompson		2.00	2.00	2.00	2.00	2.00	2.00	2.00
Prior Right		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Gorrel Ditch								
Cottonwood Irr - 1866		0.88	0.88	0.88	0.88	0.88	0.88	0.88
Cottonwood Irr - 1872			0.12	0.12				
BV Water Works	10							
BV Well No. 2								
Future Water (Estimate)		0.05	0.15	0.4	0.3	0.1		
Total Avail Water Rights	**10**	**3.93**	**4.15**	**4.4**	**4.18**	**3.98**	**3.88**	**3.88**
Max Daily Demand (2013-2020)		1.07	1.68	2.31	2.15	1.93	1.76	1.52
Max SFE Support by Month based on Average-Year Water Rights Supply vs Max Daily Demand		6,648	4,471	3,448	3,519	3,733	3,990	4,620

In an average year, Table 7 indicates the Town's water rights can support up to 3,448 SFEs in the highest demand month with the calculation outlined as follows:

Example Calculation for June (lowest number of the SFE in bottom row):

- Water rights available: 4.4 cfs
- Max Daily Demand for June: 2.31 cfs
- Current SFE Level: 1,810 SFEs
- Max supported SFEs = 4.4 cfs/2.31 cfs x 1,810 SFEs= 3,448 SFEs

Table 8 shows the dry-year water rights yield versus MDD. In the dry-year scenario, the total SFEs supported by the Town's existing water rights drops to 2,526 SFE with July being the critical month.

Table 8. Maximum SFE Based on Dry-Year for Max Daily Demand

Dry-Year Supply	Maximum Allowable Monthly Diversions, cfs							
	Nov - Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Thompson		2.00	2.00	2.00	2.00	2.00	2.00	2.00
Prior Right		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Gorrel Ditch								
Cottonwood Irr - 1866[1]		0.88	0.88	0.88	0	0	0	0
Cottonwood Irr - 1872								
BV Water Works	10							
BV Well No. 2								
Future Water		0.1	0.75	0.1				
Total Water Rights	**10**	**3.98**	**4.63**	**3.98**	**3**	**3**	**3**	**3**
Max Daily Demand (2013-2020)		1.07	1.68	2.31	2.15	1.93	1.76	1.52
Max SFE Support by Month based on Dry-Year Water Rights Supply vs Max Daily Demand		6,733	4,988	3,119	2,526	2,813	3,085	3,572

This decrease in total SFEs is mainly due to the Cottonwood Irrigating water right being subject to subordination per terms in the Case No. 83CW88 Decree, which requires protection of the St. Charles Mesa water right and low physical water availability, particularly in July through October as shown in Table 8.

Table 9 shows the dry-year water rights yield versus the maximum-day demand but applies a 20 percent reduction factor on the water demand for the months of June, July, August, and September based on potential dry-year conservation and/or restriction measures. A 20 percent reduction in water demand would equate to approximately a 25 percent improvement in SFE supported levels based on the month of July.

Table 9. Maximum SFE Based on Dry-year with Conservation for Max Daily Demand

Dry-Year Supply with Conservation	Maximum Allowable Monthly Diversions, cfs							
	Nov - Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Thompson		2.00	2.00	2.00	2.00	2.00	2.00	2.00
Prior Right		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Gorrel Ditch								
Cottonwood Irr - 1866		0.88	0.88	0.88	0	0	0	0
Cottonwood Irr - 1872								
BV Water Works	10							
BV Well No. 2								
Future Water (Estimate)		0.1	0.75	0.1				
Total Water Rights	**10**	**3.98**	**4.63**	**3.98**	**3.0**	**3.0**	**3.0**	**3.0**
Max Daily Demand (2013-2020)		1.07	1.68	1.85	1.72	1.54	1.41	1.52
Max SFE Support by Month based on Dry-Year, with Conservation Water Rights Supply vs Max Daily Demand		6,733	4,988	3,894	3,157	3,517	3,857	3,572

5.0 TOWN OF BUENA VISTA INFRASTRUCTURE

The Town utilizes an integrated water system (legal water rights and physical infrastructure) for the collection, treatment, storage, and distribution of raw and potable water. The primary infrastructure utilized in the production and delivery of the water rights portfolio are indicated on Figure 12 (page 27) and include:

5.1 Infiltration Gallery

The high-producing Infiltration Gallery groundwater source underlies the Gorrel Meadow north of Cottonwood Creek and the WTP. The Infiltration Gallery yield is enhanced through use of the Gorrel irrigation right to recharge the aquifer underlying the meadow. Groundwater that is classified as being “under the direct influence” of surface water requires filtration treatment. The Infiltration Gallery water quality to date has been such that it is <u>not</u> considered to be groundwater under direct influence (GWUDI) of surface water and therefore filtration treatment has not been required. The groundwater is collected and piped to the south side of Cottonwood Creek where sodium hydroxide (caustic soda, 50-percent solution) is fed for corrosion control and the water is disinfected prior to distribution. The disinfected water from the Infiltration Gallery flows by gravity in an 18-inch-diameter pipeline to the Lower Zone water storage tanks, which are described in more detail below.

The Infiltration Gallery has been a cost efficient water source due to its gravity flow and the fact that filtration treatment has not been necessary. However, as the Town’s water demand increases, and as water quality regulations become more stringent, it is likely that filtration treatment will be required for the Infiltration Gallery source. Even if filtration treatment is required, the Infiltration Gallery source remains valuable in that the flow through the gallery gravels and sands does not have the high turbidity that surface water flows can have.

5.2 Surface Water Diversion and Water Treatment Plant

A surface water diversion structure is located on Cottonwood Creek just above the WTP and conveys surface water to the sedimentation pond south of Cottonwood Creek prior to treatment at the WTP. The WTP was constructed in 1974 and was decommissioned in 1999. The nominal capacity of the WTP is 1.5 MGD. The general process flow for the WTP includes a 1-MG pre-sedimentation pond, chemical pretreatment, flocculation, filtration through two multi-media gravity flow filters that can be operated in parallel, a backwashing system, a 33,000-gallon clearwell, and a post-chlorination system that utilizes gas chlorine. A pilot study is currently underway to investigate water treatment alternatives to upgrade or replace the WTP.

5.3 Rodeo Grounds Well No. 1

Well No. 1 (Permit 77257-F) is a small capacity well located at the Rodeo Grounds with a reported yield of 15 gpm and an annual use of 0.2 AF (65,170 gallons). The well is also decreed as an alternate point of diversion of the Buena Vista Water Works right for 0.1 cfs (45 gpm). The well can be used only when the Water Works decree is in priority, typically the non-irrigation season.

The reported well depth is 57 feet with perforations at a depth of 37 to 57 feet. To provide a supply throughout the summer, augmentation will be required. It is not anticipated that Well No. 1 will provide service outside of the Rodeo Grounds.

5.4 Cottonwood Creek Well No 2

Well No. 2, with two Permit Numbers 78212-F (Commercial and Municipal Use) and 2221-F-R (Municipal Use), was constructed in 1999 and is located east and adjacent to the WTP and 100 feet south of Cottonwood Creek. The well depth is 100 feet, and it has a permitted pumping rate of 150 gpm (0.334 cfs). Well No. 2 has a junior water right that is rarely in priority but is used occasionally to supplement the Infiltration Gallery during times of high demand. Subsequently, when out of priority, Well No. 2 can divert through the exchange of Fry-Ark Project Water, generally in the months of November through March when streamflow at the Lower Cottonwood Creek gage is 20 cfs or greater, but the delayed depletions to Cottonwood Creek from the well pumping require replacement water. The Town has an agreement with UAWCD whereby the Town may exchange and store up to 10 AF in Cottonwood Lake in an average year and 2 AF in a dry-year. The general lack of significant augmentation water available on Cottonwood Creek limits any significant or extended use of Well No. 2, especially during dry periods.

5.5 Arkansas Well No. 3

Well No. 3 (Permit 78531-F for irrigation use) was drilled in 2015 in River Park for irrigation of 5.5 acres of playing fields and community center landscaping with an annual volume of approximately 12.3 AF. The well is tributary to the Arkansas River and the irrigation is augmented by the UAWCD global augmentation plan. The well depth is 88 feet with a screen interval between depths of 53 and 78 feet with a 10-foot tail pipe located below the screen. The stainless-steel well screen is 8 inches in diameter and the well casing has a 10-3/4-inch outside diameter. During drilling, water was encountered at a depth of 38 feet. The well is permitted for a rate of 150 gpm. The Colorado Department of Public Health and Environment (CDPHE) has approved this well as a potable water source with disinfection. A new well permit for municipal use will be required. The municipal use could also be augmented using the UAWCD global augmentation plan or, alternatively, a new water right along with an augmentation plan could be filed by the Town.

While the pump installed in Well No. 3 was the pump used for the aquifer test, data collected during the test indicate that the well is capable of pumping at a higher rate with a larger capacity pump, likely in the range of 225 to 300 gpm. A new permit from the SEO will be required for a higher pumping rate and for municipal use.

Table 10 provides a conceptual estimate of the depletion for a well withdrawal of 100 AF based upon the water use pattern of the Town. For a diversion of 100 AF from the well, the estimated return flow from the WWTP is 59.3 AF and the lawn irrigation return flow (LIRF) is 5.1 AF. The augmentation requirement to replace the depletion is estimated at approximately 35.6 AF.

Table 10. Depletion Estimate for 100 AF Diversion

Use	Diversion	Return Flow		Depletion
	AF/Yr	%	AF/Yr	AF/Yr
Indoor	65.9	90.00	59.3	6.6
Outdoor	34.1	15.00	5.1	29.0
Total	100.0	64.4%	64.4	35.6

With the Town's Buena Vista Water Works in priority from November through March, the use of an Arkansas Well is likely most cost effective in the April through October period. Table 11 outlines the conceptual monthly water use of 100 AF with an estimated augmentation requirement of approximately 45 AF. The peak diversion is 20.9 AF in June, which would require a well pumping rate of 156 gpm on a 24/7 basis. With the well pumping 16 hours per day in June, a 225 gpm pumping rate would be required for every 100 AF of supply and 45 AF of augmentation water would be required.

Table 11. Irrigation Season Depletion Estimate for 100 AF Depletion

Month	All values in AF								
	Water Diversion			Return Flow			Depletion		
	Indoor	Outdoor	Total	90% Indoor	15% Outdoor (LIRF)	Total	Indoor	Outdoor	Total
Apr	7.6	1.2	8.8	6.8	0.2	7.0	0.8	1.0	1.8
May	7.8	4.1	11.9	7.0	0.6	7.6	0.8	3.5	4.3
Jun	7.6	13.3	20.9	6.8	2.0	8.8	0.8	11.3	12.1
Jul	7.8	11.0	18.8	7.0	1.6	8.7	0.8	9.3	10.1
Aug	7.8	7.3	15.2	7.0	1.1	8.1	0.8	6.2	7.0
Sep	7.6	6.9	14.5	6.8	1.0	7.8	0.8	5.9	6.6
Oct	7.8	2.2	10.0	7.0	0.3	7.4	0.8	1.9	2.7
Total	53.9	46.1	100.0	48.5	6.9	55.4	5.4	39.2	44.6

Well No. 3 with a larger pump installed could supply 225 gpm. For municipal use from April through October, for every 100 AF of water pumped in the above pattern, an estimated 45 AF of augmentation will be required. A larger pump with a pumping rate of 225 gpm could be installed.

5.6 Fryingpan-Arkansas Project Water

Fry-Ark Project Water is not a Town water right but is water obtained by contract. The Fry-Ark Project Water includes some Arkansas River water rights (native basin water), and water from a transmountain diversion from the Frying Pan River and tributaries to the Arkansas River. The federal project is managed by Southeastern Colorado Water Conservancy District. Twin Lakes, Turquoise Lake, and Pueblo Reservoir (Figure 7, page 14) are the main storage vessels for the management of the Fry-Ark Project Water.

The Town purchases Fry-Ark Project Water typically on an annual basis, generally keeping their total allocated water at around 1,000 AF. The Town's water account is reduced to offset evaporative losses and releases from the account are made to replace out of priority depletions. Table 12 shows the Town's account balances for the past three years. On average, the Town released 38 AF of water to offset depletions and the evaporative loss was 99 AF.

Table 12. Town of Buena Vista Fry-Ark Project Water Use

Year	All Values in AF				
	Beginning of Year	Release	Evaporation	Purchase	Balance
2018	1397.59	(29.68)	(101.26)		
2019	1266.65	(46.23)	(86.84)		
2020	1133.58	(39.91)	(110.88)		
Average 2018-2017		(38.61)	(99.66)		
2021 thru June 16	982.79	(20.71)	(27.29)	70.0	1004.79

The U.S. Bureau of Reclamation website cites an average annual diversion of 69,200 AF from the Fryingpan River and its tributaries and with Arkansas River Basin supplies, the average annual water supply for the Fry-Ark Project is 80,400 AF. Based on these figures, the transmountain water supplies are 86 percent of the Project Water yield. Increased Colorado River demand can and will likely reduce the future availability of Fry-Ark Project Water throughout the Arkansas River Basin.

Project Water can be exchanged to the Town Infiltration Gallery, Town Intake, or Well No. 2, and with the agreement in place with UAWCD, Project Water can be exchanged to Cottonwood Lake or Rainbow Lake. Opportunities to perform such exchanges are limited if the instream flow water rights are not satisfied.

5.7 Water Transmission, Storage, and Distribution System

Treated potable water from the Infiltration Gallery flows by gravity via the 18-inch-diameter transmission pipeline constructed in the mid-1970s to the Lower Pressure Zone tanks. The two Lower Zone tanks have a total volume of 1.76 MG (1.5 MG and 0.26 MG). Water from the Lower Zone is pumped from the Westmoor Pump Station to the Upper Pressure Zone tanks via the 12-inch and 16-inch transmission pipelines constructed in the late 1990s. The Upper Pressure Zone has two 0.75 MG water storage tanks for a total storage volume of 1.5 MG. The distribution system, pressure zones, and associated infrastructure are shown on Figure 12 (page 27). The distribution pipelines are typically looped with a minimum size of 6-inch diameter. The Public Works Department is continually maintaining and upgrading the system as part of their annual maintenance and capital improvement program.

5.8 Westmoor Pump Station

The Westmoor pump station draws water from the Lower Pressure Zone and booster pumps deliver water into the Upper Pressure Zone and tanks.

5.9 Ivy League Pump Station

This pump station is located adjacent to the 0.26-MG storage tank and is currently offline as the Ivy League subdivision is gravity fed by the Upper Pressure Zone tanks. The Ivy League Pump Station is maintained for potential future use to provide flexibility and fill the storage tanks. It is important to note that the Ivy League subdivision potable water supply is served by the Town, but the subdivision is not within the Town municipal boundaries.

5.10 Buena Vista Sanitation District Wastewater Treatment Plant

The Buena Vista Sanitation District, a public entity created in 1953, owns and operates the WWTP. The boundaries of the Sanitation District include the Town as well as unincorporated areas within the region. The Buena Vista water rights accounting requires tracking the Town's wintertime wastewater return flows to the Arkansas River.

6.0 CURRENT AND FUTURE SUPPORTED SFE LEVELS

6.1 Current SFE Support and Timeline

The total number of SFEs the Town's existing water rights can serve under three scenarios were presented in Section 4.3 and are as follows:

Average Year	3,448 SFEs
Dry-year with Conservation	3,157 SFEs
Dry-year	2,526 SFEs

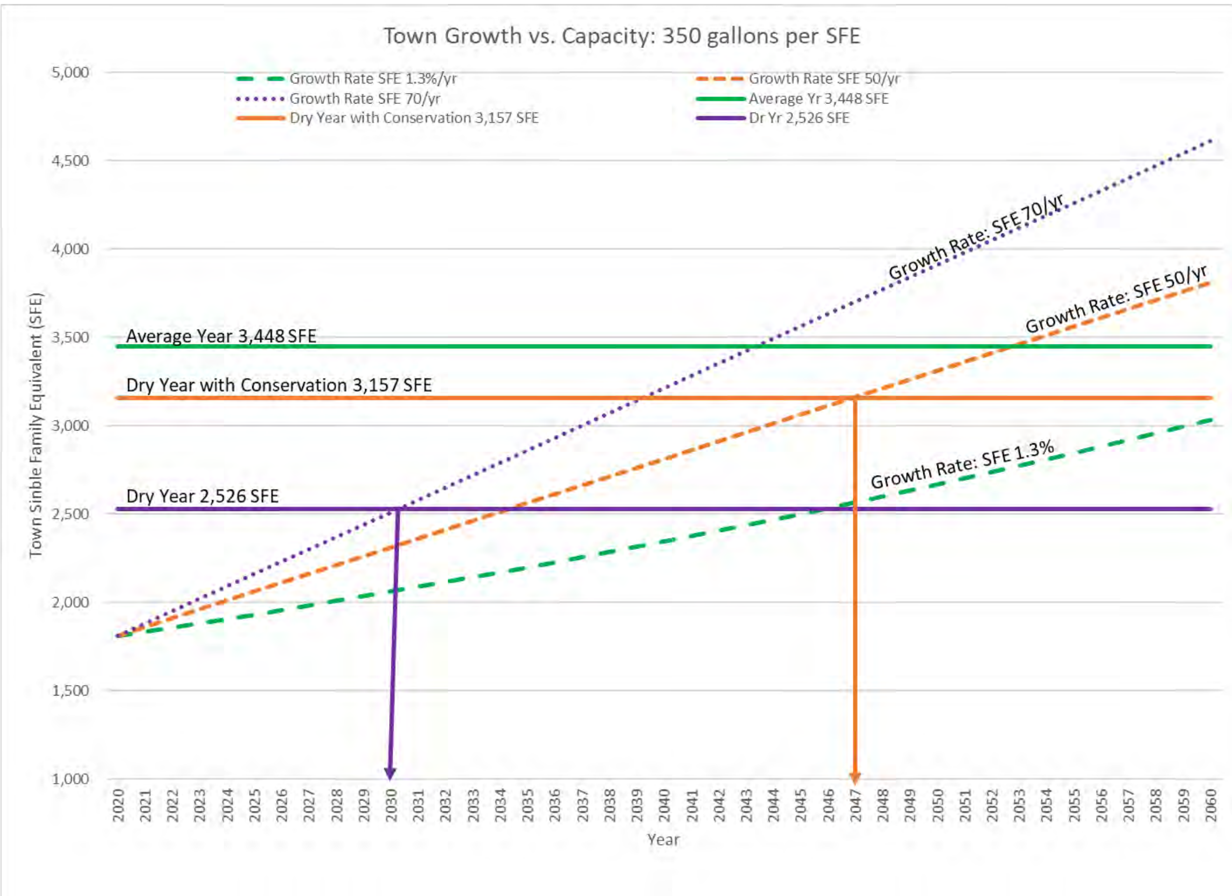
Table 13 combines the number of SFEs that can be supplied by the Town's water rights under the three scenarios along with the three growth rates analyzed to determine the year when the water rights limit is reached up to year 2060, the end of the growth projections, Table 13 is also color coded with a range from green (supply sufficient beyond year 2050) to the most critical, red year 2030 with a growth rate of 70 SFEs per year.

Table 13. Critical Years vs. Growth Scenarios for SFE Support

Scenario	SFE Growth Rate		
	1.30%	50/year	70/year
Average Year	2060+	2052	2043
Dry Year + Conservation	2060+	2047	2038
Dry Year	2046	2034	2030

Figure 13 shows the three growth rates and the three climate scenarios versus years. The figure reinforces the importance of analyzing current and future growth rates and projections based on the best available information. As demonstrated, the growth rates have a significant and material impact on when the Town would realize water stress during a dry-year.

Figure 13. SFE Projections for Various Growth Rates



6.2 Operational Flexibility and System Capabilities

The following alternatives may provide operational flexibility and physical water during future dry-years or periods of high water demand. It is intended that these alternatives provide a general road map for the Town to maintain a reliable and sustainable water supply that supports population growth, provides operational flexibility, and considers the potential impacts of climate change. Each recommendation will have different design requirements, costs, and system impacts that should be evaluated by the Town to determine the best alternatives moving forward.

6.2.1 *Acquisition of Additional Water Rights*

The search, investigation, and review of available water rights should be ongoing for the Town for growth anticipated above water rights capacities. The seniority, location, and ability to apply the water rights to beneficial use during key months in the irrigation season will be critical in determining the value and benefit of the water right to the Town. The Town should continue performing due diligence on potential water right acquisitions. To provide mid- to late summer water in a dry-year, Cottonwood Creek water rights dating 1872 or earlier are needed and these rights are few in number. Estimation of delayed irrigation return flows and planning for their replacement are factors in the assessment of a water right for purchase. Utilization of water rights junior to 1872 in conjunction with storage can be considered.

6.2.2 *Arkansas Well No. 4*

A new Arkansas Well No. 4 can provide additional flexibility for total system operation as a redundant supply that can be augmented through Fry-Ark Project Water or future water right purchases. As noted within this Plan and through discussions with the Town, it is important to consider the site's physical characteristics and location when accommodating the pumping and treatment systems. Activities are presently ongoing to investigate a location within River Park for Well No. 4, which will be tributary to the Arkansas River.

As described in Section 5.5 for Arkansas Well No. 3, for municipal use from April through October, for every 100 AF of water pumped, an estimated 45 AF of augmentation will be required. Based upon the aquifer characteristics derived from Well No. 3 testing, the Well No. 4 estimated yield for an 8-inch-diameter well with a 6-inch pump is 225 to 300 gpm (0.5 to 0.67 cfs).

6.2.3 *Fry-Ark Project Water Yield*

While the yield of Fry-Ark Project Water will likely experience yield reductions due to curtailment of transmountain diversions in drought periods, the Town should continue its practice of annually purchasing Fry-Ark Project Water.

6.2.4 *Surface Water and Groundwater Storage*

Raw water storage may be increased through participating with UAWCD in the expansion of Cottonwood Lake or Rainbow Lake, the purchasing or construction of new storage facilities, or utilizing aquifer storage and recovery to supplement and diversify the current water rights portfolio. Each storage option should be investigated based on capital and operating costs, as well as the flexibility to apply the additional water to beneficial use. At this time, the Town does not have existing water storage rights and relies on the purchase of Fry-Ark Project Water and, for the Arkansas well, trading with the UAWCD. The ability to store additional procured water is limited due to lack of available storage.

Additional water storage would allow the Town to use the water stored as a source of augmentation. Storage on Cottonwood Creek would be helpful in augmenting Well No. 2 delayed depletions and potentially allow increased use of Well No. 2.

6.2.4.1 Cottonwood Lake

Cottonwood Lake may offer some additional storage capacity through site improvements that would take place through an USFS Special Use Permit (SUP) and agreement with the UAWCD for use of storage. The location of Cottonwood Lake on South Cottonwood Creek (Figure 2, page 7) shows the potential operational benefits to the Town. Previous investigations by UAWCD preliminarily indicate the possibility of 125 AF of storage from improvements which would be shared with UAWCD. Releases of water stored in Cottonwood Lake can replace delayed depletions of the Cottonwood Creek Well No. 2. The opportunity to exchange water to Cottonwood Lake is generally in the winter months, however, in a drought period, there are winters with little to no exchange potential.

6.2.4.2 Rainbow Lake

Rainbow Lake may also offer limited storage capacity through site improvements that would take place through agreements with the UAWCD and Rainbow Lake Resort. The Rainbow Lake Resort would require thoughtful water management to meet the expectations of the resort (e.g., maintain water levels, minimize drawdown, etc.). The location of Rainbow Lake on Middle Cottonwood Creek (Figure 2, page 7) provides potential operational benefits to the Town.

6.2.4.3 General Surface Water Storage

Securing surface water storage rights would be beneficial to the Town and provide flexibility in operations and additional water to meet dry-year demand. However, the construction of additional surface water structures may be expensive and difficult based on local geomorphology and identifying a viable site for construction. Appropriate due diligence should occur for both existing or new sites that are identified to confirm the potential yield and reliability of a new water storage facility.

6.2.4.4 Aquifer Storage and Recovery

Underground water storage, or aquifer storage and recovery (ASR) is attractive in that water evaporation loss is minimized and the construction costs are less than for a typical surface water storage vessel. An aquifer storage facility allows the groundwater withdrawal similar to withdrawal of water from a surface storage reservoir. The feasibility of a large-scale aquifer storage project depends on site specifics such as the aquifer characteristics, distance, gradient, and travel time through the aquifer to the stream.

The Gorrel Meadow is not viewed as an ASR because there is very little storage and the groundwater that is not diverted by the Infiltration Gallery flows downgradient fairly rapidly.

6.2.4.5 Recharge Basins

When irrigation water rights are changed to a new use or new location, typically there are delayed irrigation return flows to the stream that must be replaced to prevent injury to other water rights. A recharge basin located on the site of the historic irrigation can be a means to replicate the historic return flows.

6.2.4.6 Alternate Transfer Mechanisms

Alternate Transfer Mechanisms (ATMs) between municipal and agricultural entities can take a few forms. Two of the most common include:

- Rotational or lease-fallowing. In this scenario, the farmer would fallow (not irrigate) a portion of their historically irrigated property and move the location of the fallowing around their property. The water "credit" derived from the fallowing of an approved project can then be used elsewhere by another party.

- Interruptible water supply agreements (IWSAs). IWSAs are temporary agreements between water right owners to allow a third party to temporarily use the water for up to three years within a 10-year period. The State Engineer's Office approves and manages these agreements.

The challenges associated with ATMs can be securing approvals from the governing body (e.g., the SEO) as well as meeting Colorado Water Law requirements to avoid injury to other senior parties. In addition, ATMs may be a short-term or temporary source of water that may not be available during dry-years and/or in the future. ATMs may be most useful as back up supplies or to be used as a supplemental supply when needed. New SFE capacity should not be predicated on ATMs.

6.3 Capacity, Upgrade, and Maintenance of Existing Infrastructure Systems

The Town's integrated water system includes both water rights and the infrastructure needed to collect, treat, and distribute water to the Town's customers. The overall limitations for future growth can be from either water rights or infrastructure. Water rights constraints are discussed in Section 4.0 and the existing infrastructure is discussed in Section 5.0. Table 14 provides a summary of the existing water system capacity constraints, with the infrastructure system being the most pressing need that the Public Works Department is in the process of addressing. The peak day demand, at times, has been met by drawing down the water level in the water storage tanks, which is okay for one or two days, but should not generally be relied upon.

Table 14. Existing Water System Constraints

Unit	Maximum Day Demand (MDD)	Infrastructure Capacity [1]		
		Infiltration Gallery	Well No. 3	Storage Drawdown
gpm	1,035	800	118	117
MGD	1.49	1.15	0.17	0.17
cfs	2.30	0.77	0.26	1.26
SFE	1,810	1,397	207	207

[1] With an infiltration gallery production rate of 800 gpm and Well No. 3 pump rate of 118 gpm, to meet the MDD, a water tank drawdown of 0.17 mg (170,000 gallons) would be required. The infiltration gallery actual yield will vary with amount of recharge applied to Meadow, precipitation and streamflow.

6.3.1 *Current Infrastructure Investigation Projects*

6.3.1.1 Gorrel Meadow Infiltration Gallery Expansion

The Town is in the process of reviewing the potential to expand the capacity of the Infiltration Gallery as well as performing a pilot study to determine the most effective filtration treatment method to provide treatment of the Infiltration Gallery water. Filtration treatment will likely be required upon expansion and even without expansion, filtration treatment will likely be required in the future due to changing water regulations or detection of a water quality parameter exceeding standards.

The proposed expansion project goal is to increase the summer capacity of the gallery from 1.15 MGD to an estimated 2.5 MGD. The expansion being investigated involves deepening of the gallery and pumping the groundwater to the filtration treatment. Though the physical capacity of the gallery may increase, the current water rights portfolio will limit the dry-year capacity to 1.94 MGD based on the current supply.

6.3.1.2 Water Treatment Plant Upgrade

Along with treatment of Infiltration Gallery water, a pilot study is currently underway to determine the necessary upgrades to or replacement of, the WTP for treatment of surface water diversions from Cottonwood Creek. The WTP was decommissioned in 1999 and will require upgrades for future use. The desired capacity for the upgrade or the replacement of the WTP is 2.5 MGD to treat both the gallery and/or surface water diversions.

6.3.1.3 Cottonwood Creek Surface Water Diversion Rehabilitation

In order to support the capacity of a redesigned WTP with surface water diversions, the intake structure of the surface water diversion headgate will require rehabilitation. The capacity of this rehabilitation will be 2.5 MGD.

7.0 CONCLUSIONS

WWE reviewed historic Master Plan reports, interviewed Town staff, investigated historic and current water demand and growth projections, and performed an in-depth review of the water rights yield during average- and dry-year scenarios. The overall conclusions from these activities are as follows:

- From a water rights perspective, the Town is currently positioned to meet the near-term water demand of its customers over the next 10-year horizon, but there is an immediate need to expand the infrastructure to meet current and future demand.

- The Town's water rights portfolio can currently support a level of 2,526; 3,157; and 3,448 SFEs under dry-year, dry-year + conservation, and average-year conditions, respectively. For reference, the 2020 SFE level is 1,810.

- Depending on the water availability, water demand, and growth rate projections, the Town could reach its water right capacity as early as 2030 during a dry-year. By contrast, at an annual population growth rate of 1.3 percent, the existing water rights are sufficient for 40+ years. While it is difficult to predict future growth rates as well as the effectiveness of local water conservation measures, it is apparent that the Town could experience water stress in the relatively short-term horizon.

- Fluctuations in population growth can have a dramatic impact on water resource planning, pointing to the importance of tracking actual growth rates and water demand for comparison to the estimates within this report and updating the master planning on a periodic basis.

- Unaccounted, or non-revenue, water accounts for a 22 to 30 percent loss when comparing raw water demand versus metered water provided to the Town's customers. This loss has an impact on revenue to the Town but can also present an opportunity for water planning as it relates to water demand. The opportunity would come in the form of finding water losses (leaks, etc.) in the system that could be resolved and provide additional future water supply.

- Dry-year yields are based on historic numbers. Analyses of Buena Vista local climate data show an increase in average summer temperature and a decrease in annual precipitation. Future conditions could be more extreme with the potential for wildfires or other conditions having an impact on water supply.

- Water rights that can provide dry-year yield to the Town are quite limited and there is strong competition for purchase of such water rights.

8.0 RECOMMENDATIONS

The Town has assembled a water rights portfolio that has served them well. The Town staff, Water Board, and Trustees understand the challenges that dry-year conditions pose in terms of water rights and infrastructure and are prudent in undertaking planning for growth and for changing conditions. Based upon analyses presented herein, the following recommendations are offered:

1. Infrastructure capacity is the most pressing need. Modify or upgrade the Infiltration Gallery and WTP immediately to meet current and future water supply demand. Proceed with connection of Arkansas Well No. 3 to the potable system, assuming the water quality monitoring underway continues to prove successful. Proceed with construction of Arkansas Well No. 4 with the understanding that Fry-Ark Project Water does likely face a reduction in the amount of transmountain diversions. The Arkansas wells are important as redundant water sources.

2. To add to the Town's water rights capacity to serve additional SFEs, the primary options include: 1) reduce the amount of unaccounted water, 2) institute a water conservation plan, and 3) purchase additional water rights and water storage.

3. Continue search to identify potential water rights within the Cottonwood Creek and Arkansas River basins for acquisition. Water rights with dry-year yield in the months of July and August (1872 or earlier priority) are most desirable for the Town, but such water rights are rarely available. For this reason, expanding the Town's water rights portfolio will likely require a combination of average year water rights and water storage. Under a high growth rate, it is possible the Town could face dry-year limitations within the next 10 years. The time required to change a water right for the Town's use should be considered in any planning scenario.

4. Continue annual purchases of Fry-Ark Project Water.

5. Participate with UAWCD in the expansion of Cottonwood Lake if the U.S. Forest Service approves the SUP for the expansion.

6. Update and track SFE growth and water demand annually along with a formal Town review to determine if the trends are more or less aggressive than the three scenarios outlined in this Plan. In addition, the potential for the Town to experience severe water stress within the next 10-year horizon would suggest that a Management Plan may be a beneficial document to determine if and when development or water restrictions may be necessary. These are reviews and conversations that should occur prior to making large development commitments or investigating the ability to supplement the Town's water supply which can take years to develop and perfect.

7. Unaccounted water is a challenge and identifying the source or reasons for the water loss will require an in-depth investigation with a potential payoff in additional revenue

and the ability to serve additional SFEs in terms of water and infrastructure capacity. Continuation of the replacement of aging distribution system piping will aid in reducing water system losses.

8. Investigate implementation of a robust conservation program for new and, possibly, existing development. A dry-year event challenge may require more aggressive restrictions. Striving for a 20 percent reduction in water demand should be a goal during the summer months (irrigation season) during a severe dry-year event.

9. Conduct a water rate study. Rate studies provide a forecast for rate stability and fairness to the water users by reviewing the current rate structure, planned capital investments, and historic financials while considering future inflationary and growth impacts. The benefits of a water rate study would be for the Town to benchmark against the rates of other similar towns and cities as well as determine the impact (and opportunity) of unaccounted/non-revenue water.

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Appendix A — Summary of Previous Water Master Plans

Parameter	RG and Associates, LLC (RG) Water Resources Master Plan, October 2014	Schmueser Gordon Meyer, Inc. (SGM) Water Resources Plan, August 2006
Population	2,670 - Yr 2014	2,860 - Yr 2005
Projected Annual Growth Rate	1.2%	3.5%
SFEs (EQR)	1,658 Existing 2,023 Remaining 3,681 Total	1,425 Existing 1,810 Future Need 3,235 Total
Persons per SFE	1.65	2.1
Average Daily Demand, MGD (cfs)	0.47 (0.72)	0.53 (0.82)
Max Day Demand (MDD), MGD (cfs)	0.94 (1.45)	1.4 (2.17)
Peaking Factor Max Day/Average Day	2.6	2.62
Water Use per SFE (or per Tap) gpd	293 (based upon Billing Records)	400 (Includes a 20% allowance for difference in diversion and metered use)
Water Rights	Ok for 20-year planning period, if growth rate increases construct Arkansas wells	Recommend Town actively pursue additional water rights on Cottonwood Creek or on the Arkansas. Gives Trigger Points when Max Day Demand = 80% of Water Right cfs

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