Appendix A. EPA Discharge Permit

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
1595 WYNKOOP STREET
DENVER, COLORADO 80202-1129

AUTHORIZATION TO DISCHARGE UNDER THE NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with the provisions of the Clean Water Act, as amended, (33 U.S.C. §1251 et seq; the "Act"),

Crow Indian Tribe

is authorized to discharge from the Crow Municipal Rural & Industrial (MR&I) Pilot Water Treatment Plant located in the northeast ¼ of Section 23, Township 4S, Range 32E, latitude 45.472222° N, longitude 107.739447° W, Bighorn County, Montana

to the Bighorn River,

in accordance with discharge point(s), effluent limitations, monitoring requirements and other conditions set forth herein. Authorization for discharge is limited to those outfalls specifically listed in the permit.

This permit shall become effective **March 1, 2015**.

This permit and the authorization to discharge shall expire at midnight, **February 29, 2020.**

Signed this 18th day of February, 2015

Authorized Permitting Official

Callie A. Videtich, Acting Assistant Regional Administrator
Office of Partnerships and Regulatory Assistance

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1. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1.1. Definitions.

The *30-day (and monthly) average*, other than for fecal coliform bacteria and total coliform bacteria, is the arithmetic average of all samples collected during a consecutive 30-day period or calendar month, whichever is applicable. Geometric means shall be calculated for fecal coliform bacteria and total coliform bacteria. The calendar month shall be used for purposes of reporting self-monitoring data on discharge monitoring report forms.

The *7-day (and weekly) average*, other than for fecal coliform bacteria and total coliform bacteria, is the arithmetic mean of all samples collected during a consecutive 7-day period or calendar week, whichever is applicable. Geometric means shall be calculated for fecal coliform bacteria and total coliform bacteria. The 7-day and weekly averages are applicable only to those effluent characteristics for which there are 7-day average effluent limitations. The calendar week, which begins on Sunday and ends on Saturday, shall be used for purposes of reporting self-monitoring data on discharge monitoring report forms. Weekly averages shall be calculated for all calendar weeks with Saturdays in the month. If a calendar week overlaps two months (i.e., the Sunday is in one month and the Saturday in the following month), the weekly average calculated for that calendar week shall be included in the data for the month that contains the Saturday.

Daily Maximum (*Daily Max.*) is the maximum measured value for a pollutant discharged during a calendar day or any 24-hour period that reasonably represents a calendar day for purposes of sampling. For pollutants with daily maximum limitations expressed in units of mass (e.g., kilograms, pounds), the daily maximum is calculated as the total mass of pollutant discharged over the calendar day or representative 24-hour period. For pollutants with limitations expressed in other units of measurement (e.g., milligrams/liter, parts per billion), the daily maximum is calculated as the average of all measurements of the pollutant over the calendar day or representative 24-hour period. If only one measurement or sample is taken during a calendar day or representative 24-hour period, the single measured value for a pollutant will be considered the daily maximum measurement for that calendar day or representative 24-hour period.

Daily Minimum (*Daily Min.*) is the minimum value allowable in any single sample or instantaneous measurement collected during the course of a day.

Grab sample, for monitoring requirements, is defined as a single "dip and take" sample collected at a representative point in the discharge stream.

Instantaneous measurement, for monitoring requirements, is defined as a single reading, observation, or measurement.

Composite samples shall be flow proportioned. The composite sample shall, at a minimum, contain at least four (4) samples collected over the compositing period. Unless otherwise specified, the time between the collection of the first sample and the last sample shall not be less than six (6) hours, nor more than twenty-four (24) hours. Acceptable methods for the preparation of composite samples are as follows:

a. Constant time interval between samples, sample volume proportional to flow rate at the time of sampling;

b. Constant time interval between samples, sample volume proportional to total flow (volume) since last sample. For the first sample, the flow rate at the time of the first sample was collected may be used;

c. Constant sample volume, time interval between samples proportional to flow (i.e., sample taken every "X" gallons of flow); and,

d. Continuous collection of sample with sample collection rate proportional to flow rate.

Bypass means the intentional diversion of waste streams from any portion of a treatment facility.

Upset means an exceptional incident in which there is unintentional and temporary noncompliance with technology-based permit effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

Severe property damage means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.

Director means the Regional Administrator of EPA Region 8 or an authorized representative.

EPA means the United States Environmental Protection Agency.

Storm Water means storm water runoff, snow melt runoff, and surface runoff and drainage.

CWA means the Clean Water Act (formerly referred to as either the Federal Water Pollution Act or the Federal Water Pollution Control Act Amendments of 1972), Pub. L. 92-500, as amended by Pub. L. 95-217, Pub. L. 95-576, Pub. L. 96-483, Pub. L. 97-117, and Pub. L. 100-4. In this permit the CWA may be referred to as "the Act."

Sewage Sludge is any solid, semi-solid or liquid residue generated during the treatment of domestic sewage in a treatment works. Sewage sludge includes, but is not limited to, domestic septage; scum or solids removed in primary, secondary or advanced wastewater treatment processes; and a material derived from sludge. Sewage sludge does not include ash generated during the firing of sewage sludge in a sewage sludge incinerator or grit and screenings generated during preliminary treatment of domestic sewage in a treatment works.

Whole Effluent Toxicity, Acute occurs when 50 percent or more mortality is observed for either species (see Part 1.3) at any effluent concentration. Mortality in the control must simultaneously be 10 percent or less for the effluent results to be considered valid.

1.2. Description of Discharge Point(s). The authorization to discharge provided under this permit is limited to those outfalls specifically designated below as discharge locations. Discharges at any location not authorized under an NPDES permit is a violation of the Clean Water Act and could subject the person(s) responsible for such discharge to penalties under Section 309 of the Act.

Outfall Serial Number(s)	Description of Discharge Point(s)
001	Any discharge of finished water from the Crow Municipal Rural & Industrial (MR&I) Pilot Water Treatment Plant to the Bighorn River. The outfall shall be located, at or near, 45.473172° N, 107.741347° W.

1.3. Specific Limitations and Self-Monitoring Requirements

1.3.1. Effluent Limitations - Outfall 001. Effective immediately and lasting through the life of this permit, the quality of effluent discharged by the facilities shall, as a minimum, meet the limitations as set forth below:

Effluent Characteristic	30-Day Average a/	Daily Maximum a/	Basis
Total Suspended Solids, mg/L	30	45	40 CFR § 133.102(b)
Total Residual Chlorine, mg/L, b/	N/A	0.019	BPJ
The pH of the discharge shall not be less than 6.0 or greater than 9.0 at any time.			40 CFR § 133.102(c)
There shall be no discharge of floating solids or visible foam in other than trace amounts. There shall be no discharge which causes a visible oil sheen in the receiving water.			BPJ, 40 CFR § 110.3
There shall be no discharge of any wastewater from the water treatment process. This includes, but is not limited to, jar testing wastewater, side stream testing wastewater, sediment/sludge, filter backwash wastewater, reverse osmosis concentrate/brine, disinfectant testing wastewater, and sanitary wastewater.			BPJ

a/ See Definitions, Part 1.1, for definition of terms.

b/ For the purposes of the permit, the minimum limit of analytical reliability in the analysis for total residual chlorine is considered to be 0.05 mg/L. For purposes of calculating averages and reporting on the Discharge Monitoring Report form, analytical values less than 0.05 mg/L shall be considered zero.

1.3.2. Self-Monitoring Requirements - Outfall 001. As a minimum, upon the effective date of this permit, the following constituents shall be monitored at the frequency and with the type of measurement indicated; samples or measurements shall be representative of the volume and nature of the monitored discharge. If no discharge occurs during the entire monitoring period, it shall be stated on the Discharge Monitoring Report Form (EPA No. 3320-1) that no discharge or overflow occurred. The following samples shall be taken from the outlet pipe from the Crow Municipal Rural & Industrial (MR&I) Pilot Water Treatment Plant to the Bighorn River.

Effluent Characteristic	Frequency	Sample Type a/
Total flow, gpm b/	Monthly	Instantaneous
Total Suspended Solids, mg/L	Weekly	Grab
Total Residual Chlorine, mg/L	Weekly	Grab
Aluminum, Total Recoverable, mg/L	Weekly	Grab
Iron, Dissolved, mg/L	Weekly	Grab
pH, s.u.	Weekly	Grab or Instantaneous

a/ See Definitions, Part 1.1, for definition of terms.

b/ Flow measurements of effluent volume shall be made in such a manner that the permittee can affirmatively demonstrate that representative values are being obtained. The average flow rate (in gallons per minute) during the reporting period and the maximum flow rate observed (in gpm) shall be reported.

1.3.3. Inspection Requirements

1.3.3.1. On at least a weekly basis, unless otherwise approved by the permit issuing authority, the permittee shall inspect the sludge ponds at a minimum, for the following:

1.3.3.1.1. Determine if a discharge is occurring;

1.3.3.1.2. Check to see if there is any leakage through the dikes;

1.3.3.1.3. Check to see if there are any animal burrows in the dike;

1.3.3.1.4. Check to see if there has been any excessive erosion of the dikes; and

1.3.3.1.5. Check to see if there are any rooted plants, including weeds growing in the water.

1.3.3.2. Each calendar year during early spring (March - April), summer (June - August), and fall (October - November), unless otherwise approved by the permit issuing authority, the permittee shall determine the following for each sludge pond: (Note: This is not required for a sludge pond if the sludge has been removed from the pond within the previous 45 days.)

1.3.3.2.1. The vertical distance from the water surface to the rim of the overflow structure, if one is present. Measurements shall be given in feet and inches.

1.3.3.2.2. The average depth of the top of the sludge blanket below the water surface of the sludge pond. At least five (5) measurements shall be made at approximately equal intervals along the long axis of the pond at approximately equal distances from the sides of the pond.

1.3.3.2.3. Based on the information on the amount of sludge accumulated in the pond and expected accumulation of sludge before the next measurements are made, the permittee shall make a determination as to whether or not the sludge needs to be removed from the pond before the next measurements are taken.

1.3.3.3. The permittee shall maintain a bound notebook recording information obtained during the inspection. At a minimum, the notebook shall include the following:

1.3.3.3.1. Date and time of the inspection;

1.3.3.3.2. Name of the inspector(s);

1.3.3.3.3. The facility's discharge status;

1.3.3.3.4. The flow rate of the discharge if occurring;

1.3.3.3.5. The findings of the observations and/or measurements required under Parts 1.3.3.1 and 1.3.3.2 above.

1.3.3.3.5. Identification of operational problems and/or maintenance problems;

1.3.3.3.6. Recommendations, as appropriate, to remedy identified problems;

1.3.3.3.7. A brief description of any actions taken with regard to problems identified; and,

1.3.3.3.8. Other information, as appropriate.

The permittee shall maintain the notebook in accordance with proper record-keeping procedures and shall make the log available for inspection, upon request, by authorized representatives of the U.S. Environmental Protection Agency or the Environmental Protection Office of the Crow Tribe.

1.3.3.3. Problems identified during the inspection shall be addressed through proper operation and maintenance. (See Part 3.5 of this permit.)

2. MONITORING, RECORDING AND REPORTING REQUIREMENTS

2.1. Representative Sampling. Samples taken in compliance with the monitoring requirements established under Part 1 shall be collected from the effluent stream prior to discharge into the receiving waters. Samples and measurements shall be representative of the volume and nature of the monitored discharge. Sludge samples shall be collected at a location representative of the quality of sludge immediately prior to use-disposal practice.

2.2. Monitoring Procedures. Monitoring must be conducted according to test procedures approved under 40 CFR Part 136, unless other test procedures have been specified in this permit. Sludge monitoring procedures shall be those specified in 40 CFR 503, or as specified in the permit.

2.3. Penalties for Tampering. The Act provides that any person who knowingly falsifies, tampers with, or renders inaccurate, any monitoring device or method required to be maintained under this permit shall, upon conviction, be punished by a fine of not more than $10,000, or by imprisonment for not more than two years, or by both. Second conviction is punishable by a fine of not more than $20,000 per day of violation, or by imprisonment of not more than four years, or both.

2.4. Reporting of Monitoring Results. Effluent monitoring results obtained during the previous month shall be summarized and reported on **one** Discharge Monitoring Report Form (EPA No. 3320-1), postmarked no later than the 28th day of the month following the completed reporting period. If no discharge occurs during the reporting period, "no discharge" shall be reported. Until further notice, sludge monitoring results may be reported in the testing laboratory's normal format (there is no EPA standard form at this time), but should be on letter size pages. Whole effluent toxicity (biomonitoring) results must be reported on the most recent version of EPA Region 8's Guidance For Whole Effluent Reporting. Legible copies of these, and all other reports required herein, shall be signed and certified in accordance with the Signatory Requirements (see Part 4), and submitted to the NPDES Program, EPA Region 8 Montana Operations Office, and the Crow Tribe at the following addresses:

original to: US EPA
NPDES Program
10 West 15th Street, Suite 3200
Helena, MT 59626

copy to: Crow Environmental Protection Office
P.O. Box 159
Crow Agency, MT 59022

2.5. Additional Monitoring by the Permittee. If the permittee monitors any pollutant more frequently than required by this permit, using test procedures approved under 40 CFR Part 136, 40 CFR Part 503, or as

specified in this permit, the results of this monitoring shall be included in the calculation and reporting of the data submitted in the DMR. Such increased frequency shall also be indicated.

2.6. Records Contents. Records of monitoring information shall include:

2.6.1. The date, exact place, and time of sampling or measurements;

2.6.2. The initials or name(s) of the individual(s) who performed the sampling or measurements;

2.6.3. The date(s) analyses were performed;

2.6.4. The time(s) analyses were initiated;

2.6.5. The initials or name(s) of individual(s) who performed the analyses;

2.6.6. References and written procedures, when available, for the analytical techniques or methods used; and,

2.6.7. The results of such analyses, including the bench sheets, instrument readouts, computer disks or tapes, etc., used to determine these results.

2.7. Retention of Records. The permittee shall retain records of all monitoring information, including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by this permit, and records of all data used to complete the application for this permit, for a period of at least three years from the date of the sample, measurement, report or application. Records of monitoring required by this permit related to sludge use and disposal activities must be kept at least five years (or longer as required by 40 CFR Part 503). This period may be extended by request of the Director at any time. Data collected on site, data used to prepare the DMR, copies of Discharge Monitoring Reports, and a copy of this NPDES permit must be maintained on site.

2.8. Twenty-four Hour Notice of Noncompliance Reporting.

2.8.1. The permittee shall report any noncompliance which may endanger health or the environment as soon as possible, but no later than twenty-four (24) hours from the time the permittee first became aware of the circumstances. The report shall be made to the EPA, Region 8, Preparedness, Assessment and Response Program at (303)293-1788, the Tribe at (406)638 -3905.

2.8.2. The following occurrences of noncompliance shall be reported by telephone to the NPDES Program, EPA Region 8 Montana Operations Office, at (406) 457-5000 (toll-free (866)457-2690) (8:00 a.m. - 4:30 p.m. Mountain Time) and the Tribe at (406)638-3905 (8:00 a.m. - 4:30 p.m. Mountain Time) by the first workday following the day the permittee became aware of the circumstances:

2.8.2.1. Any unanticipated bypass which exceeds any effluent limitation in the permit (See Part 3.7, Bypass of Treatment Facilities.);

2.8.2.2. Any upset which exceeds any effluent limitation in the permit (See Part 3.8, Upset Conditions.); or,

2.8.2.3. Violation of a maximum daily discharge limitation for any of the pollutants listed in the permit to be reported within 24 hours.

2.8.3. A written submission shall also be provided to the NPDES Program, EPA Region 8 Montana Operations Office, and to the Tribe within five days of the time that the permittee becomes aware of the circumstances. The written submission shall contain:

2.8.3.1. A description of the noncompliance and its cause;

2.8.3.2. The period of noncompliance, including exact dates and times;

2.8.3.3. The estimated time noncompliance is expected to continue if it has not been corrected; and,

2.8.3.4. Steps taken or planned to reduce, eliminate, and prevent reoccurrence of the noncompliance.

2.8.4. The Director may waive the written report on a case-by-case basis for an occurrence of noncompliance listed under Part 2.8.2 above if the incident has been orally reported in accordance with the requirements of Part 2.8.2.

2.8.5. Reports shall be submitted to the addresses in Part 2.4, Reporting of Monitoring Results.

2.9. Other Noncompliance Reporting. Instances of noncompliance not required to be reported within 24 hours shall be reported at the time that monitoring reports for Part 2.4 are submitted. The reports shall contain the information listed in Part 2.8.3.

2.10. Inspection and Entry. The permittee shall allow the Regional Administrator, or authorized representative (including an authorized contractor acting as a representative of the Administrator) upon presentation of credentials and other documents as may be required by law, to:

2.10.1. Enter upon the permittee's premises where a regulated facility or activity is located or conducted, or where records must be kept under the conditions of this permit;

2.10.2. Have access to and copy, at reasonable times, any records that must be kept under the conditions of this permit;

2.10.3. Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this permit; and,

2.10.4. Sample or monitor at reasonable times, for the purpose of assuring permit compliance or as otherwise authorized by the Act, any substances or parameters at any location.

3. COMPLIANCE RESPONSIBILITIES

3.1. Duty to Comply. The permittee must comply with all conditions of this permit. Any failure to comply with the permit may constitute a violation of the Clean Water Act and may be grounds for enforcement action, including, but not limited to permit termination, revocation and reissuance, modification, or denial of a permit renewal application. The permittee shall give the director advance notice of any planned changes at the permitted facility that will change any discharge from the facility, or of any activity that may result in failure to comply with permit conditions.

3.2. Penalties for Violations of Permit Conditions. The Clean Water Act provides for specified civil and criminal monetary penalties for violations of its provisions. However, the Federal Civil Penalties Inflation Adjustment Act of 1990, as amended by the Debt Collection Improvement Act of 1996, requires EPA to adjust the civil monetary penalties for inflation on a periodic basis. EPA previously adjusted its civil monetary penalties on December 31, 1996 (61 Fed. Reg. 69359-69365), with technical corrections and additions published on March 20, 1997 (62 Fed. Reg. 13514-13517) and June 27, 1997 (62 Fed. Reg. 35037-35041). On February 13, 2004 (69 Fed. Reg. 7121-7127) EPA once again adjusted

its civil monetary penalties. The civil and criminal penalties, as of March 15, 2004, for violations of the Act (including permit conditions) are given below:

3.2.1. Any person who violates section 301, 302, 306, 307, 308, 318 or 405 of the Act, or any permit condition or limitation implementing any such sections in a permit issued under section 402, or any requirement imposed in a pretreatment program approved under sections 402(a)(3) or 402(b)(8) of the Act, is subject to a civil penalty not to exceed $32,500 per day for each violation.

3.2.2. Any person who *negligently* violates sections 301, 302, 306, 307, 308, 318, or 405 of the Act, or any condition or limitation implementing any of such sections in a permit issued under section 402 of the Act, or any requirement imposed in a pretreatment program approved under section 402(a)(3) or 402(b)(8) of the Act, is subject to criminal penalties of $2,500 to $25,000 per day of violation, or imprisonment for not more than 1 year, or both. In the case of a second or subsequent conviction for a negligent violation, a person shall be subject to criminal penalties of not more than $50,000 per day of violation, or by imprisonment for not more than 2 years, or both.

3.2.3. Any person who *knowingly* violates sections 301, 302, 306, 307, 308, 318, or 405 of the Act, or any condition or limitation implementing any of such sections in a permit issued under section 402 of the Act, or any requirement imposed in a pretreatment program approved under section 402(a)(3) or 402(b)(8) of the Act, is subject to criminal penalties of $5,000 to $50,000 per day of violation, or imprisonment for not more than 3 years, or both. In the case of a second or subsequent conviction for a knowing violation, a person shall be subject to criminal penalties of not more than $100,000 per day of violation, or imprisonment for not more than 6 years, or both.

3.2.4. Any person who *knowingly* violates section 301, 302, 303, 306, 307, 308, 318 or 405 of the Act, or any permit condition or limitation implementing any of such sections in a permit issued under section 402 of the Act, and who knows at that time that he thereby places another person in imminent danger of death or serious bodily injury, shall, upon conviction, be subject to a fine of not more than $250,000 or imprisonment for not more than 15 years, or both. In the case of a second or subsequent conviction for a knowing endangerment violation, a person shall be subject to a fine of not more than $500,000 or by imprisonment for not more than 30 years, or both. An organization, as defined in section 309(c)(3)(B)(iii) of the CWA, shall, upon conviction of violating the imminent danger provision, be subject to a fine of not more than $1,000,000 and can be fined up to $2,000,000 for second or subsequent convictions.

3.2.5. Any person may be assessed an administrative penalty by the Administrator for violating section 301, 302, 306, 307, 308, 318 or 405 of this Act, or any permit condition or limitation implementing any of such sections in a permit issued under section 402 of this Act. Where an administrative enforcement action is brought for a Class I civil penalty, the assessed penalty may not exceed $11,000 per violation, with a maximum amount not to exceed $32,500. Where an administrative enforcement action is brought for a Class II civil penalty, the assessed penalty may not exceed $11,000 per day for each day during which the violation continues, with the maximum amount not to exceed $157,500.

3.3. Need to Halt or Reduce Activity not a Defense. It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

3.4. Duty to Mitigate. The permittee shall take all reasonable steps to minimize or prevent any discharge or sludge use or disposal in violation of this permit which has a reasonable likelihood of adversely affecting human health or the environment.

3.5. Proper Operation and Maintenance. The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used

by the permittee to achieve compliance with the conditions of this permit. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems which are installed by a permittee only when the operation is necessary to achieve compliance with the conditions of the permit. However, the permittee shall operate, as a minimum, one complete set of each main line unit treatment process whether or not this process is needed to achieve permit effluent compliance.

3.5.1 The permittee shall, as soon as reasonable and practicable, but no later than six (6) months after the effective date of this permit, do the following as part of the operation and maintenance program for the wastewater treatment facility:

3.5.1.1. Have a current O & M Manual(s) that describes the proper operational procedures and maintenance requirements of the wastewater treatment facility;

3.5.1.2. Have the O & M Manual(s) readily available to the operator of the wastewater treatment facility and require that the operator become familiar with the manual(s) and any updates;

3.5.1.3. Have a schedule(s) for routine operation and maintenance activities at the wastewater treatment facility; and,

3.5.1.4. Require the operators to perform the routine operation and maintenance requirements in accordance with the schedule(s).

3.5.2. The permittee shall maintain a daily log in a **bound notebook(s)** containing a summary record of all operation and maintenance activities at the wastewater treatment facility. At a minimum, the notebook shall include the following information:

3.5.2.1. Date and time;

3.5.2.2 Name and title of person(s) making the log entry;

3.5.2.3. Name of the persons(s) performing the activity;

3.5.2.4. A brief description of the activity; and,

3.5.2.5. Other information, as appropriate.

The permittee shall maintain the notebook in accordance with proper record-keeping procedures and shall make the log available for inspection, upon request, by authorized representatives of the U.S. Environmental Protection Agency or the Crow Tribe.

3.6. Removed Substances. Collected screenings, grit, solids, sludge, or other pollutants removed in the course of treatment shall be buried or disposed in a manner consistent with all applicable federal and tribal regulations (i.e., 40 CFR Part 257, 40 CFR Part 258, 40 CFR Part 503) and in a manner so as to prevent any pollutant from entering any waters of the United States or creating a health hazard. **In addition, the use and/or disposal of sewage sludge shall be done under the authorization of an NPDES permit issued for the use and/or disposal of sewage sludge by the appropriate NPDES permitting authority for sewage sludge.** Sludge/digester supernatant and filter backwash shall not be directly blended with or enter either the final plant discharge and/or waters of the United States.

3.7. Bypass of Treatment Facilities.

3.7.1. Bypass not exceeding limitations. The permittee may allow any bypass to occur which does not cause effluent limitations to be exceeded, but only if it also is for essential maintenance to assure efficient operation. These bypasses are not subject to the provisions of Parts 3.7.2 and 3.7.3.

3.7.2. Notice:

3.7.2.1. Anticipated bypass. If the permittee knows in advance of the need for a bypass, it shall submit prior notice, if possible at least 10 days before the date of the bypass to the NPDES Program, EPA Region 8 Montana Operations Office, and the Tribe.

3.7.2.2. Unanticipated bypass. The permittee shall submit notice of an unanticipated bypass as required under Part 2.8, Twenty-four Hour Noncompliance Reporting, to the NPDES Program, EPA Region 8 Montana Operations Office, and the Tribe.

3.7.3. Prohibition of bypass.

3.7.3.1. Bypass is prohibited and the Director may take enforcement action against a permittee for a bypass, unless:

3.7.3.1.1. The bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;

3.7.3.1.2. There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgement to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance; and,

3.7.3.1.3. The permittee submitted notices as required under Part 3.7.2.

3.7.3.2. The Director may approve an anticipated bypass, after considering its adverse effects, if the Director determines that it will meet the three conditions listed above in Part 3.7.3.1.

3.8. Upset Conditions

3.8.1. Effect of an upset. An upset constitutes an affirmative defense to an action brought for noncompliance with technology based permit effluent limitations if the requirements of Part 3.8.2 are met. No determination made during administrative review of claims that noncompliance was caused by upset, and before an action for noncompliance, is final administrative action subject to judicial review (i.e., Permittees will have the opportunity for a judicial determination on any claim of upset only in an enforcement action brought for noncompliance with technology-based permit effluent limitations).

3.8.2. Conditions necessary for a demonstration of upset. A permittee who wishes to establish the affirmative defense of upset shall demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence that:

3.8.2.1. An upset occurred and that the permittee can identify the cause(s) of the upset;

3.8.2.2. The permitted facility was at the time being properly operated;

3.8.2.3. The permittee submitted notice of the upset as required under Part 2.8, Twenty-four Hour Notice of Noncompliance Reporting; and,

3.8.2.4. The permittee complied with any remedial measures required under Part 3.4, Duty to Mitigate.

3.8.3. Burden of proof. In any enforcement proceeding, the permittee seeking to establish the occurrence of an upset has the burden of proof.

3.9. Toxic Pollutants. The permittee shall comply with effluent standards or prohibitions established under Section 307 (a) of the Act for toxic pollutants within the time provided in the regulations that establish those standards or prohibitions, even if the permit has not yet been modified to incorporate the requirement.

3.10. Changes in Discharge of Toxic Substances. Notification shall be provided to the Director as soon as the permittee knows of, or has reason to believe:

3.10.1. That any activity has occurred or will occur which would result in the discharge, on a routine or frequent basis, of any toxic pollutant which is not limited in the permit, if that discharge will exceed the highest of the following "notification levels."

3.10.1.1. One hundred micrograms per liter (100 ug/L);

3.10.1.2. Two hundred micrograms per liter (200 ug/L) for acrolein and acrylonitrile; five hundred micrograms per liter 500 ug/L) for 2,4-dinitrophenol and for 2-methyl-4,6-dinitrophenol; and one milligram per liter (1 mg/L) for antimony;

3.10.1.3. Five (5) times the maximum concentration value reported for that pollutant in the permit application in accordance with 40 CFR § 122.21(g)(7); or,

3.10.1.4. The level established by the Director in accordance with 40 CFR § 122.44(f).

3.10.2. That any activity has occurred or will occur which would result in any discharge, on a non-routine or infrequent basis, of a toxic pollutant which is not limited in the permit, if that discharge will exceed the highest of the following notification levels:

3.10.2.1. Five hundred micrograms per liter (500 ug/L);

3.10.2.2. One milligram per liter (1 mg/L) for antimony;

3.10.2.3. Ten (10) times the maximum concentration value reported for that pollutant in the permit application in accordance with 40 CFR § 122.21(g)(7); or,

3.10.2.4. The level established by the Director in accordance with 40 CFR § 122.44(f).

4. GENERAL REQUIREMENTS

4.1. Planned Changes. The permittee shall give notice to the Director as soon as possible of any planned physical alterations or additions to the permitted facility. Notice is required only when:

4.1.1. The alteration or addition could significantly change the nature or increase the quantity of pollutant discharged. This notification applies to pollutants which are not subject to effluent limitations in the permit; or,

4.1.2. There are any planned substantial changes to the existing sewage sludge facilities, the manner of its operation, or to current sewage sludge management practices of storage and disposal. The permittee shall give the Director notice of any planned changes at least 30 days prior to their implementation.

4.1.3. The alteration or addition to a permitted facility may meet one of the criteria for determining whether a facility is a new source.

4.2. Anticipated Noncompliance. The permittee shall give advance notice to the Director of any planned changes in the permitted facility or activity which may result in noncompliance with permit requirements.

4.3. Permit Actions. This permit may be modified, revoked and reissued, or terminated for cause. The filing of a request by the permittee for a permit modification, revocation and reissuance, or termination, or a notification of planned changes or anticipated noncompliance, does not stay any permit condition.

4.4. Duty to Reapply. If the permittee wishes to continue an activity regulated by this permit after the expiration date of this permit, the permittee must apply for and obtain a new permit. The application should be submitted at least 180 days before the expiration date of this permit.

4.5. Duty to Provide Information. The permittee shall furnish to the Director, within a reasonable time, any information which the Director may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit. The permittee shall also furnish to the Director, upon request, copies of records required to be kept by this permit.

4.6. Other Information. When the permittee becomes aware that it failed to submit any relevant facts in a permit application, or submitted incorrect information in a permit application or any report to the Director, it shall promptly submit such facts or information.

4.7. Signatory Requirements. All applications, reports or information submitted to the Director shall be signed and certified.

4.7.1. All permit applications shall be signed by either a principal executive officer or ranking elected official.

4.7.2. All reports required by the permit and other information requested by the Director shall be signed by a person described above or by a duly authorized representative of that person. A person is a duly authorized representative only if:

4.7.2.1. The authorization is made in writing by a person described above and submitted to the Director; and,

4.7.2.2. The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility, such as the position of plant manager, superintendent, position of equivalent responsibility, or an individual or position having overall responsibility for environmental matters. (A duly authorized representative may thus be either a named individual or any individual occupying a named position.)

4.7.3. Changes to authorization. If an authorization under Part 4.7.2 is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of Part 4.7.2 must be submitted to the Director prior to or together with any reports, information, or applications to be signed by an authorized representative.

4.7.4. Certification. Any person signing a document under this section shall make the following certification:

> "I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

4.8. Penalties for Falsification of Reports. The Act provides that any person who knowingly makes any false statement, representation, or certification in any record or other document submitted or required to be maintained under this permit, including monitoring reports or reports of compliance or noncompliance shall, upon conviction be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than six months per violation, or by both.

4.9. Availability of Reports. Except for data determined to be confidential under 40 CFR Part 2, all reports prepared in accordance with the terms of this permit shall be available for public inspection at the offices of the Director. As required by the Act, permit applications, permits and effluent data shall not be considered confidential.

4.10. Oil and Hazardous Substance Liability. Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under Section 311 of the Act.

4.11. Property Rights. The issuance of this permit does not convey any property rights of any sort, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor any infringement of federal, state, tribal or local laws or regulations.

4.12. Severability. The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit, shall not be affected thereby.

4.13. Transfers. This permit may be automatically transferred to a new permittee if:

4.13.1. The current permittee notifies the Director at least 30 days in advance of the proposed transfer date;

4.13.2. The notice includes a written agreement between the existing and new permittees containing a specific date for transfer of permit responsibility, coverage, and liability between them; and,

4.13.3. The Director does not notify the existing permittee and the proposed new permittee of his or her intent to modify, or revoke and reissue the permit. If this notice is not received, the transfer is effective on the date specified in the agreement mentioned in Part 4.13.2.

4.14. Permittees in Indian Country. EPA is issuing this permit pursuant to the Agency's authority to implement the Clean Water Act NPDES program in Indian country, as defined at 18 U.S.C. 1151.

4.15. Reopener Provision. This permit may be reopened and modified (following proper administrative procedures) to include the appropriate effluent limitations (and compliance schedule, if necessary), or other appropriate requirements if one or more of the following events occurs:

4.15.1. Water Quality Standards: The water quality standards of the receiving water(s) to which the permittee discharges are modified in such a manner as to require different effluent limits than contained in this permit.

4.15.2. Wasteload Allocation: A wasteload allocation is developed and approved by the CrowTribe and/or EPA for incorporation in this permit.

4.15.3. Water Quality Management Plan: A revision to the current water quality management plan is approved and adopted which calls for different effluent limitations than contained in this permit.

4.16. Toxicity Limitation-Reopener Provision. This permit may be reopened and modified (following proper administrative procedures) to include whole effluent toxicity limitations if whole effluent toxicity is detected in the discharge.

Crow Tribe Water Resources

CROW MR&I SYSTEM

WATER TREATMENT PLANT ALTERNATIVE ANALYSIS REPORT

JUNE 2015

BARTLETT & WEST

CROW TRIBE

CROW MR&I SYSTEM

WATER TREATMENT PLANT ALTERNATIVE ANALYSIS REPORT

CROW TRIBE

CROW TRIBE WATER RESOURCE DEPARTMENT

JUNE 15, 2015

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1 Introduction and Background

1.1 Description of the Crow MR&I Water System

The MR&I System is a water supply and delivery system that will be constructed to meet the domestic, commercial, and industrial water needs of residents and communities on the Crow Indian Reservation. The authorization of the MR&I System is a result of the Claims Resolution Act of 2010 (Public Law 111-291). Title IV of this Act is the Crow Tribe Water Rights Settlement which, in part, authorized $246,381,000 for the design and construction of the MR&I System.

The Act defines the MR&I System as generally described in the document entitled "Crow Indian Reservation Municipal, Rural and Industrial Water System Engineering Report" prepared by DOWL HKM (Authorizing Report), and dated July 2008 and updated in a status report prepared by DOWL HKM dated December 2009.

The Authorizing Report briefly discusses the use of Mechanical Pre-filters, Microfiltration Membranes, Ultraviolet Disinfections, Chlorine and Ammonia in the water treatment process. The Authorizing Report does not elaborate on why these components were selected since this was a feasibility level document. It is critical to note that the Authorizing Report had utilized a different intake location and type than what is currently being proposed. Processes may vary from earlier based on different water quality parameters.

This Water Treatment Plant Preliminary Process Design Report (Report) is a preliminary/feasibility design document in which technically feasible treatment processes will be considered and evaluated. Options may be eliminated from future consideration for cost, residuals-environmental, water quality goals, or implementation/operational reasons. This report will also identify the processes to be carried into the bench scales and pilot scale testing level.

1.2 Populations, Water Demands, and Master Plan Information

The Crow Indian Reservation, the largest of the seven Indian reservations in Montana, is located in south-central Montana, bordered by Wyoming to the south and the Northern Cheyenne Indian Reservation to the east. The Crow Indian Reservation encompasses approximately 2,300,000 acres, which includes the northern end of the Bighorn Mountains, Wolf Mountains, and Pryor Mountains. Approximately 404,172 acres of land within the reservation are owned by the Crow Tribe and the Bighorn River is the largest hydrologic feature on the reservation. Flowing north from the Montana-Wyoming state line through the center of the reservation to the Little Bighorn River just outside Hardin, Montana, the Bighorn River continues north to its confluence with the Yellowstone River. Incidentally, part of the western reservation boundary runs along the ridgeline separating Pryor Creek and the Yellowstone River, and the city of Billings is approximately 10 miles northwest of this reservation boundary.

There are 6 cities, towns, or communities located on the Crow Reservation. The largest cities, according to the 2010 population census, are Crow Agency (1616), Fort Smith (161), Lodge Grass (428), Pryor (618), Saint Xavier (83), and Wyola (215). The only incorporated community on the Reservation is the town of Lodge Grass. The City of Hardin(3505), which is located on the Northeastern corner just outside of the reservation boundary was also analyzed in previously completed Engineering Reports as a possible bulk service connection to the Crow Indian Reservation MR&I System. The population of the entire Reservation (2010 census) was 6,863 of which approximately 78% was Indian and 22% was non-Indian. The projected 2060 population based on Census information is 9,050 while the projected population based on Tribal Enrollment figures is closer to 12,000.

Water needs for the entire Reservation were analyzed within the 2014 Crow MR&I Master Plan Report [1]. The combined water demand for the entire Reservation, including Municipal, Rural (including livestock), and Industrial users is 3,154 gallons per minute peak, approximately 4.5 MGD. Of this livestock water usage across the system is estimated at 0.79 MGD or 550

gallons per minute peak transmission flow. Included within this 4.5 MGD is approximately 0.65 MGD or 450 gallons per minute peak for Industrial use. The remaining 3.06 MGD is municipal and rural household/residential usage. If the community of Hardin connects to the system the demand is 4,660 gallons per minute peak, approximately 6.7 MGD. Should the population growth experienced more closely match the Tribal Enrollment forecast than the US Census information the demand may be as high as approximately 8.0-8.5 MGD.

Complete population projections, water demand criteria, water treatment regulations, raw water quality & quantity parameters, water treatment process technology, system cost estimates, and preliminary project schedule are all included in the 2014 Crow MR&I Master Plan Report [1].

2 Water Quality Data, Treatment Goals, Water Costs & Socioeconomic Effects

2.1 Raw Water Information

Surface water sampling of the Big Horn River has been conducted to obtain low and high, along with average water quality of the river. The construction of the pilot well was affected due to delays with obtaining a BIA Surface Use Agreement for the well construction. It was determined that surface water sampling would be conducted until a pilot well could be constructed. Initial surface water quality data was collected via grab samples from the Bighorn River over the summer months of June, July and August 2013. Grab samples were analyzed for pH, temperature, conductivity, total hardness, alkalinity, total iron, total manganese, and tubidity. During this period, one grab sample was collected and provided to a testing laboratory to test for a variety of biological and physical properties, inorganics, nutrients, metals and radionuclides. A list of the parameter results for the field and lab analysis can be found in Appendix A. This initial data set from 2013 along with information gathered from the USGS gauging station and the city of Hardin water treatment plant provided a baseline of information.

In spring of 2014, sampling began on a broad range of parameters not initially tested in 2013, including those note above in the grab sampling; as well as TSS, TDS, TOC/DOC, microbiological, UV 254, odor, additional total and dissolved metals, non-metals and organics, inorganics, nutrients, TTHM potential, HAA5 potential, radiological parameters, recent weather conditions, and river flow rate. Repeating field and laboratory analysis provided a more thorough characterization of the source water. Source water sampling has continued through 2014 with a focus on the parameters that were detected in this sample set. The sample set was used to establish a scheduled sampling program for the present and expected parameters necessary to inform the designers of the treatment process and EPA permitting of the pilot plant and ultimate water treatment plant. The results of the 2014 testing are displayed in Appendix A.

In the fall of 2014, an additional sample site was added; an observation well located approximately 300’ north of the planned pilot well. The well was installed during geotechnical investigation of the site and is approximately 20’ in depth and constructed of 2” PVC/PVC screen. This sample location provides an approximate characterization of the ground water under the influence of Big Horn River surface water. The results of the fall 2014 lab and grab sample testing are displayed in Appendix A.

The ongoing surface water and GWUISW sampling is focused on the parameters that will be either most impacting to the treatment design and or complex to treat. These parameters include TOC, DOC, hardness, alkalinity, iron and manganese and others. The list of parameters, frequency and approximate scheduled end date of the ongoing sampling is included in Appendix A.

Table 2.1(a): Source Water (Observation Well) Sampling Results-9/12/14 through 1/30/15

Summary of Pilot Observation Well Water								
	pH	Temp °C	Turbidity (NTU)	ORP (mv)	T. Hardness (mg/L)	Alkalinity (mg/L)	Iron (mg/L)	Manganese (mg/L)
Count	7	8	8	7	9	9	9	9
Max	7.83	15	1.33	-37	285	240	0.73	0.77
Average	7.57	11.7	0.61	-42	258	213	0.49	0.75
Min	7.47	9.6	0.27	-54	239	185	0.37	0.72
	DOC (mg/L)	TOC (mg/L)	UVA 254 (cm^{-1})	TSS (mg/L)	TDS (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Bromide (mg/L)
Count	6	6	4	4	3	4	4	4
Max	3	3.3	0.383	0	522	10	176	0
Average	2.9	2.9	0.16475	0	496	9.25	164.25	0
Min	2.6	2.4	0.08	0	472	9	157	0
	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Orthopho-sphate (mg/L)	Total Phosphorous (mg/L)	Dissolved Aluminum (mg/L)	Dissolved Boron (mg/L)	Dissolved Calcium (mg/L)
Count	4	4	4	4	4	4	4	4
Max	0.57	0	0	0.124	0.253	0.41	0.19	70
Average	0.43	0	0	0.0795	0.14625	0.1125	0.13	48.1
Min	0.34	0	0	0.04	0.101	0	0.1	0.54
	Dissolved Magnesium (mg/L)	Dissolved Silicon (mg/L)	Dissolved Sodium (mg/L)	Dissolved Strontium (mg/L)	Total Aluminum (mg/L)	Total Arsenic (mg/L)	Total Calcium (mg/L)	Total Iron (mg/L)
Count	4	4	4	4	4	4	4	3
Max	24	11.7	114	0.70	9.69	0.006	72	0.6
Average	20	10.3	82.25	0.65	2.4225	0.0045	65.5	0.57
Min	17	9	63	0.59	0	0.004	58	0.48
	Total Manganese (mg/L)	Total Selenium (mg/L)	Total Silicon (mg/L)	Total Silica (mg/L)	Total Uranium (mg/L)	Gross Alpha (pCi/L)	Radium 226 (pCi/L)	Radium 228 (pCi/L)
Count	4	4	4	1	4	2	2	2
Max	0.743	0	32	10.5	0.003	5.6	0.5	0.4
Average	0.677	0	15.575	10.5	0.0016	4.8	0.35	0.25
Min	0.601	0	10	10.5	0.001	4	0.2	0.1
	Total Zinc (mg/L)	*Non-Detect Parameters						
Count	4	Antimony	Copper	Silver				
Max	0.04	Beryllium	Lead	Thallium				
Average	0.01	Cadmium	Mercury	Chlorophyll-a				
Min	0	Chromium	Nickel	Cyanide				

2.2 Treated Water Quality Requirements & Goals

The Crow Tribe has made it a priority to construct a new Water Treatment Plant that produces high quality drinking water, addresses ease of operation concerns, and provides the Crow Tribe a potential economic impact and jobs creation source. Goals for the water treatment plant processes include compliance with current and future regulations (specifically future Disinfection Byproducts), operation performance and reliability, affordability of water to system users, and expandability. Although these goals will increase the cost to produce high quality drinking water, the Crow Tribal Chairman and CTWRD Director have approved these secondary goals above the required primary standards to treat the water. The cost for production of this high quality drinking water will be the responsibility of the Crow Tribal members and any other users connected to the system.

High quality water determined by the Crow Tribe will be defined by four parameters:

1. Requirement-Water produced will meet the Safe Drinking Water Act (SDWA), including:
    a. National Primary Drinking Water Regulations [Appendix B]
    b. Stage 1 and Stage 2 Disinfection / Disinfection By Product Rule (D/DBPR)
    c. Lead and Copper Rules
    d. Total Coliform Rule
    e. LT2ESWTR
    f. Filter Backwash Recycling (FBRR) Rule

2. Goal- Water produced shall be softened from the raw water hardness level of "Very Hard" (approximately 180-300+ mg/l as $CaCO_3$) to "Moderately Hard" (125-150 mg/l as $CaCO_3$) or less.

3. Goal- Effluent Water quality will meet National Secondary Drinking Water Standards [Appendix B] for contaminants of concern, such as iron, manganese and aluminum.

4. Goal -Effluent Water quality will achieve sufficient total organic carbon (TOC) reduction to minimize disinfection by-product (DBP) formation to 10% lower than regulatory mandates, with a goal being 33% lower than the regulatory limit. DBP formation potential and simulated distribution system testing will utilize free chlorine and chloramines as distribution system residual disinfectants, will be performed during the bench and pilot study to determine the required TOC removal through the treatment process to achieve DBP compliance with the respective disinfectants.

5. Goal- Flexibility of the selected process to adapt and have the ability to achieve the potential treatment goals presented by future regulations. Water will be compliant with potential future regulations specifically Nitrosodimethylamine (NDMA) and the formation of other nitrogenous disinfection by products associated with Chloramines.

Table 2.2(a): Crow MR&I Treatment Quality Goals - May 2014 through February 2015

Contaminant	Crow MR&I Goal	MCL-Required Limit	Source-Surface Water Sample Range	Source- RBF Well Sample Range
Primary Standards-Requirements [4]				
Secondary Standards-Goals				
Sulfate	< 200 mg/L	250 mg/L[2]	255-273 mg/L	157-176 mg/L
Iron	<0.05 mg/L	0.3 mg/L[2]	0.02-0.05 mg/L	0.5-0.6 mg/L
Manganese	<0.03 mg/L	0.05 mg/L[2]	0.01-0.02 mg/L	0.6-0.7 mg/L
Aluminum	<0.1 mg/L	0.2 mg/L[2]	0.2-0.6 mg/L	ND-0.4 mg/L
Chloride	<250 mg/L	250 mg/L[2]	12-13 mg/L	9-10 mg/L
TDS	<500 mg/L	500 mg/L[2]	561-613 mg/L	472-522 mg/L
Non –Standards-Goals				
Hardness[2]	125 mg/l as CaCO3	NA	176-322 mg/L Approximately	239-285 mg/L Approximately
TOC[1]	1.25 mg/L*	NA-DBP Precursor	3.0-3.5 mg/L	2.4-3.3 mg/L
Disinfectant Byproducts				
TTHMs	Below MCL	80 ug/L	97-236 ug/L[3]	97-236 ug/L[3]
HAA5	Below MCL	60 ug/L	100-161 ug/L[3]	100-161 ug/L[3]
Bromate[1]	Below MCL	10 ug/L	NA	ND - < 1ug/L

[1]*Bromide & TOC are Disinfection Byproduct precursors.*

[2]*Not a regulated standard but typical desired range is 100-200 mg/L*

[3]*Maximum TTHM and HAA5 Potential of the sample taken. TTHM contained an initial free chlorine reading of 0.01 mg/L and HAA5 contain 0.04 mg/L. Samples were spiked with a 5% sodium hypochlorite solution the lab and incubated for 7 days at 25˚ C before analysis. Final free chlorine after incubation was 0.41 mg/L in the TTHM sample and 0.71 mg/L in the HAA5 sample.*

[4]*See Appendix B for All Primary standard as well as source water sample ranges*

** EPA's recommended TOC goal of 1.25 mg/L will be further evaluated following Bench & Pilot testing. TOC Reduction Requirements are applicable. A Hardness reduction goal of 125 mg/L will also be considered further following the Bench & Pilot testing.*

Table 2.2 (b): Design Considerations

Treatment Considerations	Technical Considerations	Financial Considerations
TOC Reduction necessary to-minimize Disinfection Byproduct precursors	MR&I Water Treatment Plant must have the flexibility of treatment processes to meet current & future regulations as well as the challenges of a large distribution system	Capital Costs
Iron & Manganese Removal is needed	Minimize Labor Intensity	OM&R Costs
Hardness reduction is desired by the Crow Tribe	Decrease Technical Difficulty	Labor Costs (part of OM&R costs)
Treatment of Secondary Goals desired by the Crow Tribe (Secondary Goals include Aluminum, Chloride, TDS, Sulfate	Water Treatment Plant must be able to successfully permit the residuals removal	Residuals Handling Costs (part of OM&R costs)
Treatment to meet all required Primary Standards		MR&I system and Water Treatment Plant provides the Crow Tribe the potential for economic impact and jobs source
Compliance Future Regulations – Specifically minimize NDMA formation (with the use of Chloramines)		

2.3 Socioeconomic Effects & Considerations

Items noted below are many of the socioeconomic effects and considerations of a new regional water treatment plant providing high quality water to the people of the Crow Reservation.

- Improved health
    - Reduced sulfate = reduced gastrointestinal illnesses & dehydration
    - Reduced nitrate = reduced infant illness & mortality
    - Reduced uranium = reduced kidney toxicity
    - Reduced Manganese = reduced respiratory problems & neurological damage

    - Reduced healthcare costs
- Improved safety
    - Larger flows are available along transmission pipelines which allow for potential for firefighting in rural areas; (Note-fire flows are not available in all pipelines, design criteria will allow water to be taken from transmission pipelines but design does not include fire flow and is not available in any capacity in the smaller distribution lines, community tanks contain additional storage for fire flow within communities)
- Expansion and upgrade abilities
- Tribal Operation for all water delivered on the Reservation is from one single entity, the Crow Tribe
    - One organization operating, maintaining, and managing the water system
- Jobs creation during construction and operations & maintenance
- Increased property valves
- Decrease in water deposit on pipes and appliances
    - Increase longevity of:
        - Water heaters – up to 50% longer
        - Washers – up to 30%
        - Toilets – up to 70%
        - Water faucets – up to 40%
        - Dishwashers – up to 30%
    - Increase efficiency of water heaters – up to 25%
    - Decreased repair and replacement costs
- Cleaning
    - Fabrics last longer when laundered in soft water
    - Decreased time to clean
    - Removal of manganese staining of laundry
- Potential for increased economic development
- Increased tax revenue due to increased economic activity and property values
    - Benefit for school districts
- Increased water availability could lead to new industries and job development on the reservation
- Decrease scaling of pipes due to softened water
    - Extend distribution system life
- Centralized softening rather than home softeners; an outreach program with the Crow Tribe Water Resource Department is continuing to work to reach out to the public within the system and educate them further

3 Treatment Process Alternatives

3.1 Potential Treatment Technologies

Many water treatment process technologies can be utilized to the meet the treatment goals and requirements identified. The complete water treatment process train must provide the following:

1. Filtration process to remove contaminants, pathogens, other impurities in the source water.
2. Soften source water
3. TOC reduction process to reduce chlorinated DBP precursors and possible future regulated micro-pollutants.
4. Pretreatment process to remove Iron and Manganese
5. Treatment process to enhance Radionuclide removal. Uranium is of particular concern in the Crow Nation. Approximately 2/3's of the individual wells tested indicate uranium levels at or near the MCL of 30 ug/L. Source water sampling indicates levels at 1-6.4 ug/L, there for under the current treatment requirements.

See 2014 Crow MR&I Master Plan Section 6.5 for description of technologies. The Bureau of Reclamation also provides a summary of contaminant and treatment technologies located in Appendix C.

Filtration Process	Advantages	Disadvantages
Media Filtration	Tried and true history of use Normally lower Capital and O&M Costs than Membrane Filtration Does not require Chemical cleans like Membranes	Allows for passage of larger colloidal / particulate matter than Membrane filters More sensitive to source water changes, less repeatable with varying source water Less Log removal of Viruses, Giardia, Cryptosporidium than membranes Less Log removal by filtration requires more disinfection Log credits Larger footprint requirement Increased operator expertise required for operation
Microfiltration/Ultrafiltration	Established technology Small filtration size than media filters provides greater barrier to pathogens, containments Filtration is very reliable and repeatable; integrity testing provides a consistent method of maintaining this reliability Smaller filtration size allows for a greater possibility of meeting future more stringent regulations Ability to start and stop	Normally higher capital and O&M costs than media filtration Chemical cleans are required Membrane replacement costs

	operations and maintain performance Higher Log removal of Viruses, Giardia, Cryptosporidium than media filtration	
BAC Filtration	Provides some level of Organics removal Normally lower Capital and O&M Costs than Membrane Filtration	Starting and stopping of process may disrupt biological activity and changes in effluent quality produced Less Log removal of Viruses, Giardia, Cryptosporidium than membranes

Table 3.1 (a): Filtration Processes Considered

Description of the technologies (Microfiltration & Ultrafiltration, Media Filtration, and Biological Activated Carbon Filtration) are located in Appendix C:

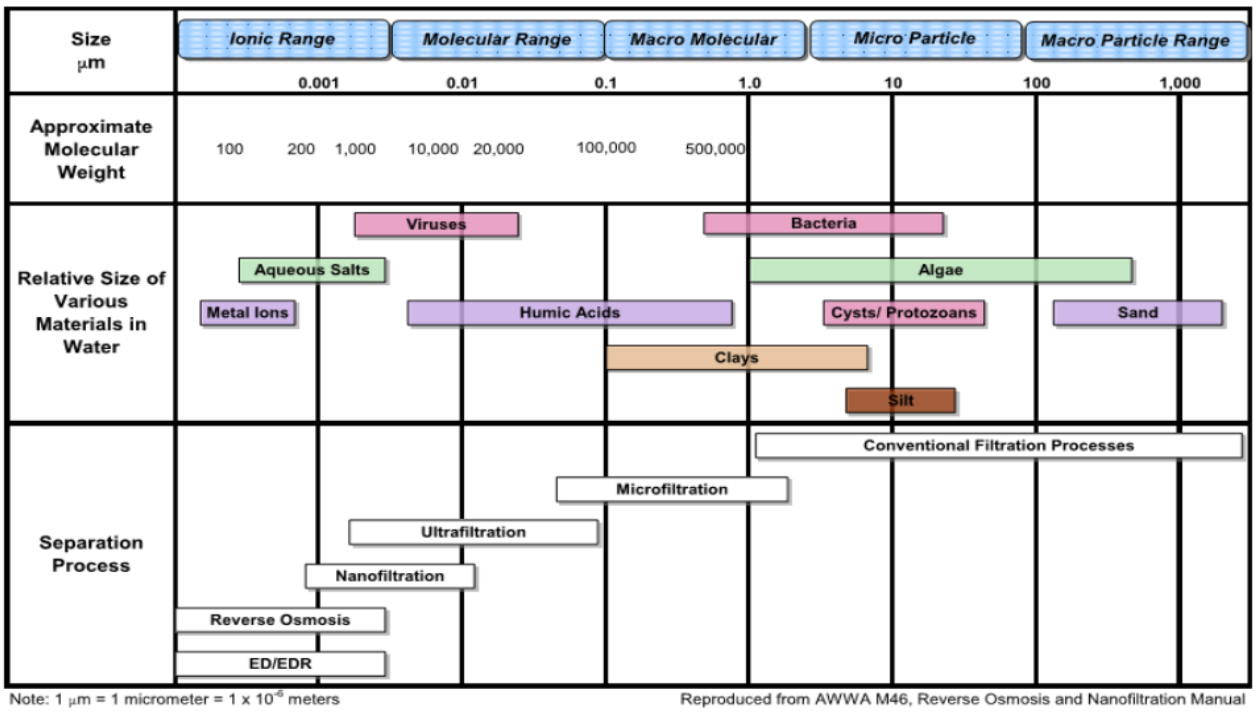

Table 3.1 (b): Filtration Sizes

Table 3.1 (c): Softening Processes Considered

Filtration Process	Advantages	Disadvantages
Reverse Osmosis (RO)/Nanofiltration (NF)	Tried and true history of use in water treatment Additional Pathogen barrier beyond filtration Highest removal of TOC, taste & odor, uranium, other pollutants Provides removal of DBP Precursors, Nitrate, hardness, TDS, Sulfates, Uranium, radionuclides all in one process Ability to start and stop operations and maintain performance Easy capacity increase for future expansion Low labor operation	Higher capital cost and O&M than other softening options Large chemical demands with cleaning and anti-scalants Large quantity of concentrated waste stream; residuals discharge difficulties Membranes are not oxidant tolerant High Feed Pressures Membrane fouling and scaling can occur if the pretreatment and/or RO system is not operated correctly for a given water quality Water stabilization may be required following treatment, which requires chemistry knowledge and effects of bypassing / blending.
Lime Softening	Established technology Normally lower Capital and O&M Costs than RO/NF Provides softened water to desired level	Handling of lime-both storing, feeding, and cleaning Starting and stopping of process may disrupt lime sludge and change effluent quality produced Lower Organics-TOC-DBP precursor reduction than other softening options Large lime sludge & solids residuals to dispose of Labor requirements High level chemistry knowledge needed for operation
Ion Exchange-Miex®/MICo®	Provides good level of Organics removal Provides hardness reduction Capital costs are typically equal to or slightly lower than other softening options Pretreatment Option	Established technology but less utilized than other softening technology considered Large quantity of concentrated waste brine; residual discharge difficulties Ion exchange resin must be regenerated periodically Labor requirements
Electrodialysis (EDR) Softening (EDR)	Softening and removal ability is similar to NF/RO	Very limited suppliers –one Significant capital and Operating costs

	Oxidant tolerant membranes Automated Process Low chemical addition for pretreatment Low feed pressure	Large quantity of concentrated waste stream; residuals discharge difficulties

Description of the softening technologies (Reverse Osmosis (RO)/Nanofiltration (NO), Lime Softening, Ion Exchange Miex®, EDR) are located in Appendix C:

Table 3.1 (d): Pretreatment & Post-treatment Process Options Considered

Filtration Process	Advantages	Disadvantages
PAC Pretreatment Feed	Can be fed in basin as powder or slurry Organic removal as well has taste and odor	Cannot be fed with chlorine or potassium permanganate PAC sludge disposal, not able to be regenerated
GAC Post-treatment Contactor	Well Established Organic removal as well has taste and odor	Expensive O&M cost for regeneration Requires close monitoring
Ion Exchange-Miex® Pretreatment	Provides good level of Organics removal Pretreatment Option	Large quantity of concentrated waste brine; residuals discharge difficulties Ion exchange resin must be regenerated periodically Labor requirements Can be used with PAC dosing
Pretreatment Coagulation/Flocculation/Sedimentation-Clarifier, Plate Settler	Plate Settler-High loading rate, small footprint Clarifier-Can incorporate lime softening, long history of use in water treatment	Plate Settler-Maintenance of mixer, flocculators, sludge collection system Clarifier-high equipment costs, high level operation skill & labor, optimal performance with polymer
Oxidation for Iron-MN Removal	Options for oxidant-Ozone, Permanganate, etc.	Potential byproduct formation; pre-oxidation can lead to increased levels of TTHMs, HAA5s, Bromate
Greensand Filtration	Relatively low cost Proven & Reliable	Oxidation required Backwash disposal along with regeneration

Description of the pretreatment-post treatment technologies (Greensand Filtration, Oxidation, Ozone, and GAC-PAC) are located in Appendix C:

Table 3.1 (e): Water Treatment Processes Barrier Table

Treatment Process	Iron-Manganese	Biological (Filtration)	TOC-DBP Precursors	Hardness	TDS	Sulfate	Aluminum	Radionuclides (Uranium)
Media Filtration		X						
MF/UF		X						
BAC Filtration		X	X					
NF/RO			X-High	X	X	X	X	X
Lime Softening	X		X-Low	X				X
Ion Exchange-MIEX®			X	X		X		X
EDR		X	X	X	X	X	X	
PAC Pretreatment			X					
GAC Post-Treatment			X					

Ion-Exchange Pretreatment			X					
Pretreatment-Coag/Floc/Sed Clarifier or Plate Settlers	X							
Oxidation-FE/MN Removal	X							
Greensand Filtration	X							

As discussed in previous sections of this report, the Crow Tribe has strongly indicated their desire to provide high quality drinking water meeting Primary Drinking Water requirements as well as treating for Secondary Drinking Water Standards noted to provide benefits to the residence of the Crow Reservation. The expense to treat the water to the secondary goals identified is greater than treating to primary standards, but the Crow Tribal Chairman and CTWRD Director have approved this process on behalf of the residency of the Crow Reservation.

3.2 Residuals Considerations

A large part of any treatment process selection is the consideration of the residuals. Management and permitting of water treatment plant residuals can be a difficult and take a long period of time. The following table summarizes the residuals streams produced by each treatment process identified in previous sections.

Table 3.2 (a): Residuals of Processes Considered

Residuals	Liquid Residuals				Solid Residuals	
Treatment Process	Brine /Concentrate	Back wash	Rinse Water	Neutralized Water	Spent Resin /Media	Sludge
Media Filtration		X				X
MF/UF		X	X	X		
BAC Filtration		X				X
NF/RO	X		X			

Lime Softening		X			X	X
Ion Exchange-MIEX®	X	X	X			
EDR	X		X			
PAC Pretreatment						X
GAC Post-Treatment					X	
Ion-Exchange Pretreatment	X	X	X		X	
Pretreatment-Coag/Floc/Sed Clarifier or Plate Settlers		X			X	X
Oxidation-FE/MN Removal						
Greensand Filtration		X				

Since the Radionuclides (Uranium, Radium, Beta & Alpha Particles) source water levels are all below the MCL it is not likely that the residuals concentration will significantly concentrated. The waste streams for the ion exchange, lime softening-drying beds, and NF/RO are specifically the processes of concern and are described further in the Mass Balance Diagrams.

Table 3.2 (b): Residuals Disposal Options

Residuals	Disposal Options			
	Surface Water Discharge	Discharge to onsite ponds	Underground Injection	Surface Application-Landfill
Liquids	X	X	X	
Sludge		X		X
Spent Resin/Media/Membranes				X

Additional residuals disposal investigation and agency discussions will take place upon receiving the pilot residuals information. Preliminary discussions with the EPA, MT Fish, Wildlife, & Parks, US Army Corps of Engineers, MT DEQ, and local NRCS have provided no indication that any of the options noted above are not feasible. Following the piloting project, coordination meeting(s) will be conducted to

review the residuals options with Federal, Tribal, and Local agencies with interest. Reclamation has authored a report regarding the treatment of concentrate [2] which provides additional information of the treatment and disposal requirement of concentrate streams.

3.3 Treatment Process Train Alternative Preliminary Development

Below is the preliminary list of all alternatives developed to meet the Crow Tribe's water treatment goals for preliminary review.

1. **Alternative Process No. 1 –** PAC Feed with Lime Softening Clarification, MF/UF Filtration, Chlorine Disinfection
2. **Alternative Process No. 2 –** MIEX Pretreatment, Lime Softening Clarification, MF/UF Filtration, Chlorine Disinfection
3. **Alternative Process No. 3 –**Lime Softening Clarification, MF/UF Filtration, GAC Contactor, Chlorine Disinfection
4. **Alternative Process No. 4 –**Pretreatment Oxidation, Lime Softening Clarification, MF/UF Filtration, Chlorine Disinfection
5. **Alternative Process No. 5 –**Lime Softening Clarification, MF/UF Filtration, Chloramine Disinfection
6. **Alternative Process No. 6 –** PAC Feed with Lime Softening Clarification, Media Filtration, Chlorine Disinfection
7. **Alternative Process No. 7 –** Ion Exchange Pretreatment, Lime Softening Clarification, Media Filtration, Chlorine Disinfection
8. **Alternative Process No. 8 –**Lime Softening Clarification, Media Filtration, GAC Contactor, Chlorine Disinfection
9. **Alternative Process No. 9 –**Pretreatment Oxidation, Lime Softening Clarification, Media Filtration, Chlorine Disinfection
10. **Alternative Process No. 10 –**Lime Softening Clarification, Media Filtration, Chloramine Disinfection
11. **Alternative Process No. 11-** Pretreatment Oxidation-Coagulation-Sedimentation, Lime Softening Clarification, Biologically Active Media Filtration, Chlorine Disinfection
12. **Alternative Process No. 12-** Pretreatment Oxidation-Coagulation-Sedimentation, Media Filtration, NF/RO Softening, Chlorine Disinfection
13. **Alternative Process No. 13-** Pretreatment Coagulation-Sedimentation, Greensand Media Filtration, NF/RO Softening, Chlorine Disinfection
14. **Alternative Process No. 14-** Pretreatment Oxidation-Coagulation-Sedimentation, MF/UF Filtration, NF/RO Softening, Chlorine Disinfection
15. **Alternative Process No. 15 –** Pretreatment Oxidation-Coagulation-Sedimentation, Biologically Active Filtration, NF/RO Softening, Chlorine Disinfection
16. **Alternative Process No. 16 –** PAC Feed with Pretreatment Coagulation-Sedimentation, MF/UF Filtration, ED/EDR Softening, Chlorine Disinfection
17. **Alternative Process No. 17 –**Pretreatment Coagulation-Sedimentation, MF/UF Filtration, ED/EDR Softening, GAC Contactor, Chlorine Disinfection
18. **Alternative Process No. 18 –** MIEX Pretreatment with Oxidation Pretreatment Coagulation-Sedimentation, MF/UF Filtration, ED/EDR Softening Chlorine Disinfection
19. **Alternative Process No. 19 –** Pretreatment Oxidation-Coagulation-Sedimentation, MIEX Softening, MF/UF Filtration, Chlorine Disinfection
20. **Alternative Process No. 20 -** Pretreatment Oxidation-Coagulation-Sedimentation, MIEX Softening, Media Filtration, Chlorine Disinfection

Crow MR&I Water Treatment Process Alternatives							Treatment Goals									Decision to Move Investigation Forward		
							Organic Matter Removal											
Process Option No.	Treatment Group	Process Train Components					Primary	Secondary	Hardness Removal	Iron & Manganese	Aluminum	TDS	Uranium/ Arsenic/ Sulfates	Filtration-	Disinfection	Accepted for Further Investigation	Why not carried forward	Notes
1	Lime Softening & MF/UF	PAC Pretreatment	Lime Softening	MF/UF	Chlorine	pH, Recarbonation	PAC-10%	Lime Softening (10% - 30%)	Lime Softening	PAC/Lime			Lime	MF/UF	Chlorine	No	DOC Reduction less than Goal; PAC dosages will be high, PAC contact would be long, FE-MN Removal inadequate to meet goal	
2	Lime Softening & MF/UF	MIEX Pretreatment	Lime Softening	MF/UF	Chlorine	pH, Recarbonation	MIEX-35%	Lime Softening (10% - 30%)	Lime Softening	MIEX/Lime	MIEX	MIEX	Lime, MIEX	MF/UF	Chlorine	Yes		Oxidation removed from analysis but still an option-dependent on lime softening bench FE-MN removal; MIEX not softening-TOC removal
3	Lime Softening & MF/UF	Lime Softening	MF/UF	GAC Post Filtration	Chlorine	pH, recarbonation	GAC-50% +	Lime Softening (10% - 30%)	Lime Softening	Lime			Lime	MF/UF	Chlorine	Yes		Oxidation removed from analysis but still an option; depend on lime softening bench FE-MN removal
4	Lime Softening & MF/UF		Lime Softening	MF/UF	Chlorine	pH, Recarbonation	Lime Softening (10% - 30%)		Lime Softening	Lime			Lime	MF/UF	Chlorine	No	Insufficient DOC removal	
5	Lime Softening & MF/UF	Lime Softening	MF/UF	Chloramines	pH, Recarbonation		Lime Softening (10% - 30%)		Lime Softening	Lime			Lime	MF/UF	Chloramines	No	Concerns over future regulations with NDMA and Chloramines, Nitrification concerns in distribution system	Chloramines still an option with other TOC reduction processes considered
6	Lime Softening & Media Filtration	PAC	Lime Softening	Media	Chlorine	pH, Recarbonation	PAC-10%	Lime Softening (10% - 30%)	Lime Softening	PAC/Lime			Lime	Media Filtration	Chlorine	No	DOC Reduction less than Goal; PAC dosages will be high, PAC contact would be long, FE-MN Removal inadequate to meet goal	
7	Lime Softening & Media Filtration	MIEX	Lime Softening	Media	Chlorine	pH, Recarbonation	MIEX-35%	Lime Softening (10% - 30%)	Lime Softening	MIEX/Lime	MIEX	MIEX	Lime, MIEX	Media Filtration	Chlorine	Yes		Oxidation removed from analysis but still an option-dependent on lime softening bench FE-MN removal; MIEX not softening-TOC removal
8	Lime Softening & Media Filtration	Lime Softening	Media	GAC	Chlorine	pH, recarbonation	GAC-50% +	Lime Softening (10% - 30%)	Lime Softening	Lime			Lime	Media Filtration	Chlorine	Yes		Oxidation removed from analysis but still an option; depend on lime softening bench FE-MN removal
9	Lime Softening & Media Filtration	Oxidation	Lime Softening	Media	Chlorine	pH, Recarbonation	Lime Softening (10% - 30%)		Lime Softening	Oxidation			Lime	Media Filtration	Chlorine	No	Insufficient DOC removal	
10	Lime Softening & Media Filtration	Lime Softening	Media	Chloramines	pH, Recarbonation		Lime Softening (10% - 30%)		Lime Softening	Lime			Lime	Media Filtration	Chloramines	No	Concerns over future regulations with NDMA and Chloramines, Nitrification concerns, in dist. System	chloramines still an option with other TOC reduction processes considered
11	Bio Filter	Ozone	Lime Softening	Bio Filter	Chlorine	pH, Recarbonation	Bio Filter 20%-40%	Lime Softening (10% - 30%)	Lime Softening	Pre Oxidation			Lime	Bio Filter	Chlorine	Yes		Operational Concerns, temperatures, weekend shut downs, Bio Filters are difficult to develop in a lab-bench testing environment, Consider anthracite or GAC for biofilter media, If biofilter is
12	NF/RO	Pre Oxidation Coag/Sed	Media	NF/RO	Chlorine		NF/RO-95% + RO Permeate, 60-70% Blended		RO/NF	Pre Oxidation	NF/RO	NF/RO	NF/RO	Media Filtration	Chlorine	No	If media filtration, greensand provide s additional MN removal	
13	NF/RO	Potassium Permanganate	Coag/Sed	Greensand Media	NF/RO	Chlorine	NF/RO-95% + RO Permeate, 60-70% Blended		RO/NF	Potassium Permanganate (Ox) & Greensand Media	NF/RO	NF/RO	NF/RO	Greensand Media	Chlorine	Yes		Possible pre-oxidation of Mn required if NF/RO blend is insufficient, Coag/Sed could be eliminated if NF/RO blend is sufficient to remove DOC
14	NF/RO	Oxidation	Coag/Sed	MF/UF	NF/RO	Chlorine	NF/RO-95% + RO Permeate, 60-70% Blended		RO/NF	Pre Oxidation	NF/RO	NF/RO	NF/RO	MF/UF	Chlorine	Yes		Oxidation kinetics of Mn are slow, ozone could biofoul membranes
15	Bio Filter	Ozone	Coag/Sed	Bio Filter	NF/RO	Chlorine	NF/RO-95% + RO Permeate, 60-70% Blended	Bio Filter 20%-40%	NF/RO	Ozone (Ox) & Coag/Sed	NF/RO	NF/RO	NF/RO	Bio Filter	Chlorine	No	Operational Concerns, Biofouling on RO from BAC, TOC reduction to the level not necessary,	Biofouling concerns with Bio filter in front on RO
16	ED/EDR	PAC	Coag/Sed	MF/UF	ED/EDR	Chlorine	EDR 60-70%	PAC 10%	ED/EDR		EDR	EDR	EDR	MF/UF	Chlorine	No	One manufacturer, Costs, future Replacement, EDR Complexity of operation and O&M, PAC dosage will be high to achieve DOC removal	
17	ED/EDR	Coag/Sed	MF/UF	ED/EDR	GAC	Chlorine	EDR 60-70%	GAC 50%	ED/EDR	Pre Oxidation	EDR	EDR	EDR	MF/UF	Chlorine	No	One manufacturer, Costs, or Future Replacement, EDR complexity	
18	ED/EDR	MIEX	Coag/Sed	MF/UF	ED/EDR	Chlorine	MIEX 35%	Coag/Sed	ED/EDR		EDR, MIEX	EDR	MIEX, EDR	MF/UF	Chlorine	No	One manufacturer, Costs, or Future Replacement, Potential scaling of IX resin dependent on WQ.	
19	MIEX	MIEX	Oxidation	Coag/Sed	MF/UF	Chlorine	MIEX 35%	Coag/Sed	MIEX	Pre Oxidation	MIEX		MIEX	MF/UF	Chlorine	No	DOC Reduction less than Goal, Potential scaling of IX resin dependent on WQ. ~15% Increase in TDS with IX softening.	
20	MIEX	MIEX	Oxidation	Coag/Sed	Media	Chlorine	MIEX 35%	Coag/Sed	MIEX	Pre Oxidation	MIEX		MIEX	Media Filtration	Chlorine	No	DOC Reduction less than Goal, Potential scaling of IX resin dependent on WQ. ~15% Increase in TDS with IX softening.	

Notes
Lime Softening DOC Removal - Standard (10%), Sludge Recycle (up to 30%), https://etd.ohiolink.edu/letd.send_file?accession=osu1047486107&disposition=inline
MIEX DOC Removal - 35%, March 2015 Orica-MIEX Report
PAC DOC Removal - 10%, http://pubs.usgs.gov/sir/2013/5001/section11.html
BAC DOC Removal - 20-40%, file:///C:/Users/jjh01103/Downloads/hozalski-jawwa-1995.pdf
EDR - http://cdn.intechweb.org/pdfs/13751.pdf

Table 3.3(a): Complete Process Train Alternative

A number of process technologies were initially noted as alternatives to be considered. During the initial water treatment process alternative analysis process it was determined that there are 7 options to be evaluated further. The options that were not moved forward contained the technologies discussed in the next paragraphs based on the concerns and potentially issues identified.

Powder Activated Carbon was withheld from further investigation as a pretreatment organic removal process based on the relatively high dosages that would be required along with the organic reduction being less than that of other pretreatment options. A PAC feed system is still a possibility during final analysis.

Based on concerns over future regulation compliance with EPA standards for NDMA (Nitrosodimethylamine) as well as Nitrification with the distribution system Chloramine disinfection was not carried forward for further evaluation within this report. Correspondence received from the EPA was a factor in these concerns. A chloramination disinfection system is still a possibility during final analysis and design.

Electro-dialysis Reversal (EDR) membranes were not carried into the further analysis portion of the report due to several issues identified. These issues include: limited manufacturers, future replacement issues, complexity of O&M, and costs-both capital and operating. These items were the main reasons for not considering the EDR system as one of the most beneficial process technology options.

The MIEX Ion Exchange technology was initially considered as a softening option. After initial manufacturer's bench scale information was reviewed it was determined that the organic reduction level did not meet the project DOC reduction goal. This along with potential issues with ion exchange resin scaling and increase in TDS due utilizing the technology for softening led to the determination to not carry the technology forward. MIEX is still a pretreatment organic removal option when paired with lime softening for enhanced organics removal.

3.4 Treatment Process Train Alternatives Considered for Further Evaluation

Following the alternate review process the number of processes that were determined to be most beneficial for Further Evaluation were identified. The seven alternatives are discussed in detail below. All seven are seen as robust treatment scenarios based on desktop information available. Schematics of these alternatives are provided in section 3.5.1.1.

1. *Alternative Train No. 1* - Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels, Micro/Ultra Filtration; Chlorine

   In this treatment process the initial step will be Lime Softening clarification. This process includes clarification, coagulation, and flocculation. A coagulant or polymer along with lime is fed during this process. This step will oxidize iron and manganese and will remove hardness, iron & manganese, along with other flocculated materials. Accommodations in design may be made to be able to provide a pretreatment oxidation step prior to either the MIEX or Lime Softening steps. Several oxidation options are possible to oxidize the iron and manganese present in the source water. These options are ozone, chlorine, and permanganate. The ozone oxidation would provide treatment for iron & manganese as well as the option to treat for taste and odor compounds. Taste and odor events are unlikely given intake facility being considered and the source water information collected. The MIEX Pressure filters

would follow the lime softening process and would provide additional organics removal, iron/manganese removal, and softening. Consideration will be given for the location of MIEX system to placed either prior to or follow the Lime Softening process. The water is then filtered through MF/UF to remove pathogens, turbidity, and other particulates in the water. The final step is to then disinfect the filtered water with chlorine prior to distribution. Space can be left for future ammonia system which along with the chlorine system could be used to disinfect by chloramination.

2. *Alternative Train No. 2* – Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation) Micro/Ultra Filtration; GAC Vessels, Chlorine

In this treatment process the initial step will be Lime Softening clarification. This process includes clarification, coagulation, and flocculation. A coagulant or polymer along with lime is fed during this process. This step will oxidize iron and manganese and will remove hardness, iron & manganese, along with other flocculated materials. Accommodations in design may be made to be able to provide a pretreatment oxidation step prior to the Lime Softening steps. Several oxidation options are possible to further oxidize the iron and manganese present in the source water should the lime softening not provide enough removal. These options are ozone, chlorine, and permanganate. The water is then filtered through MF/UF to remove pathogens, turbidity, and other particulates in the water. After the filtration step the water flows to the GAC Pressure filters for post treatment organics removal. The GAC also would provide treatment for taste and odor compounds. The final step is to then disinfect the filtered water with chlorine prior to distribution. Space can be left for future ammonia system which along with the chlorine system could be used to disinfect by chloramination.

3. *Alternative Train No. 3* - Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels; Media Filtration; Chlorine

In this treatment process the initial step will be Lime Softening clarification. This process includes clarification, coagulation, and flocculation. A coagulant or polymer along with lime is fed during this process. This step will oxidize iron and manganese and will remove hardness, iron & manganese, along with other flocculated materials. Accommodations in design may be made to be able to provide a pretreatment oxidation step prior to either the MIEX or Lime Softening steps. Several oxidation options are possible to oxidize the iron and manganese present in the source water. These options are ozone, chlorine, and permanganate. The ozone oxidation would provide treatment for iron & manganese as well as the option to treat for taste and odor compounds. Taste and odor events are unlikely given intake facility being considered and the source water information collected. The MIEX Pressure filters would follow the lime softening process and would provide additional organics removal, iron/manganese removal, and softening. Consideration will be given for the location of MIEX system to placed either prior to or follow the Lime Softening process. The water is then filtered through media filters (GAC, anthracite, sand, and/or combination) to remove pathogens, turbidity, and other particulates in the water. The final step is to then disinfect the filtered water with chlorine prior to

distribution. Space can be left for future ammonia system which along with the chlorine system could be used to disinfect by chloramination.

4. *Alternative Train No. 4* – Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Media Filtration; GAC Vessels, Chlorine

In this treatment process the initial step will be Lime Softening clarification. This process includes clarification, coagulation, and flocculation. A coagulant or polymer along with lime is fed during this process. This step will oxidize iron and manganese and will remove hardness, iron & manganese, along with other flocculated materials. Accommodations in design may be made to be able to provide a pretreatment oxidation step prior to the Lime Softening steps. Several oxidation options are possible to further oxidize the iron and manganese present in the source water should the lime softening not provide enough removal. These options are ozone, chlorine, and permanganate. The water is then filtered through media filters (GAC, anthracite, sand, and/or combination) to remove pathogens, turbidity, and other particulates in the water. After the filtration step the water flows to the GAC Pressure filters for post treatment organics removal. The GAC also would provide treatment for taste and odor compounds. The final step is to then disinfect the filtered water with chlorine prior to distribution. Space can be left for future ammonia system which along with the chlorine system could be used to disinfect by chloramination.

5. *Alternative Train No. 5* – Pretreatment Oxidation (Ozone), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Bio GAC Media Filtration, Chlorine

In this treatment process the initial treatment step is the pretreatment oxidation. Several oxidation options are possible to oxidize the iron and manganese present in the source water. With bio filtration being utilized ozone would be required to break up the organic material present. Ozone oxidation converts some of the total organic carbon (TOC) to biodegradable dissolved organic carbon (BDOC). To promote biological activity ozone is added upstream to the filter beds. Ozone may be applied prior to rapid mix or the biofilter. The ozone oxidation would also provide the flexibility for treatment of taste and odor compounds. Following this step the water is sent to the Lime Softening process. This process includes clarification, coagulation, and flocculation. A coagulant or polymer along with lime is fed during this process. This step will remove hardness, iron & manganese, along with other flocculated materials. The water is then filtered through biologically active GAC media filters to remove pathogens, turbidity, and other particulates in the water. The biological active component of the filter also will provide some organics removal. The final step is to then disinfect the filtered water with chlorine prior to distribution. Space can be left for future ammonia system which along with the chlorine system could be used to disinfect by chloramination.

6. *Alternative Train No. 6* - (Pretreatment Oxidation, Coagulation, Sedimentation) Greensand Media Filtration; NF/RO Softening, Chlorine

   In this treatment process the initial treatment step is the pretreatment oxidation, coagulation, and sedimentation. Several oxidation options are possible for the removal of the iron and manganese present in the source water. These options are ozone, chlorine, and permanganate. Several coagulants are options as well; Aluminum Sulfate, Ferric Chloride, Polyaluminum Chloride, along with proprietary chemical designer options. Following the oxidation; coagulation and sedimentation steps will settle a portion of the iron & manganese and potentially other contaminants that have formed into floc. The water is then filtered through greensand media filters to remove pathogens, turbidity, and other particulates in the water. The greensand media following the oxidation step provides iron and manganese removal. If it is determined during bench testing that the greensand filter is sufficient for iron and manganese removal the coagulation and sedimentation step can possibly be removed. Following the filtration step the water would flow through the NF/RO membranes. This step will remove hardness, organics, micro-pollutants, TDS, and others. A portion of the NF/RO permeate water is blended with the filtrate effluent in order to achieve the desired water stability. The final step is to then disinfect the filtered water with chlorine prior to distribution. Space can be left for future ammonia system which along with the chlorine system could be used to disinfect by chloramination.

7. *Alternative Train No. 7* - Pretreatment Oxidation, Coagulation, Sedimentation, Micro/Ultra Filtration; NF/RO Softening, Chlorine

   In this treatment process the initial treatment step is the pretreatment oxidation, coagulation, and sedimentation. Several oxidation options are possible for the removal of the iron and manganese present in the source water. These options are ozone, chlorine, and permanganate. Several coagulants are options as well; Aluminum Sulfate, Ferric Chloride, Polyaluminum Chloride, along with proprietary chemical designer options. Following the oxidation; coagulation and sedimentation steps will remove the iron & manganese and potentially other contaminants. The water is then filtered through MF/UF membranes to remove pathogens, turbidity, and other particulates in the water. Following the filtration step the water would flow through the NF/RO membranes. A portion of the NF/RO permeate water is blended with the filtrate effluent in order to achieve the desired water stability. The NF/RO step will remove hardness, organics, micro-pollutants, TDS, and others. The final step is to then disinfect the filtered water with chlorine prior to distribution. Space can be left for future ammonia system which along with the chlorine system could be used to disinfect by chloramination

3.5 Evaluation of Treatment Process Train Alternatives

3.5.1 Treatment Train Schematics

In the following pages schematics for each of the 7 options are shown. These schematics are meant to be general in nature, with flow and removal characteristics included within the mass balance diagrams.

CROW MR&I SYSTEM
WATER TREATMENT PLANT PROCESS FLOW SCHEMATIC
ALTERNATIVE 1

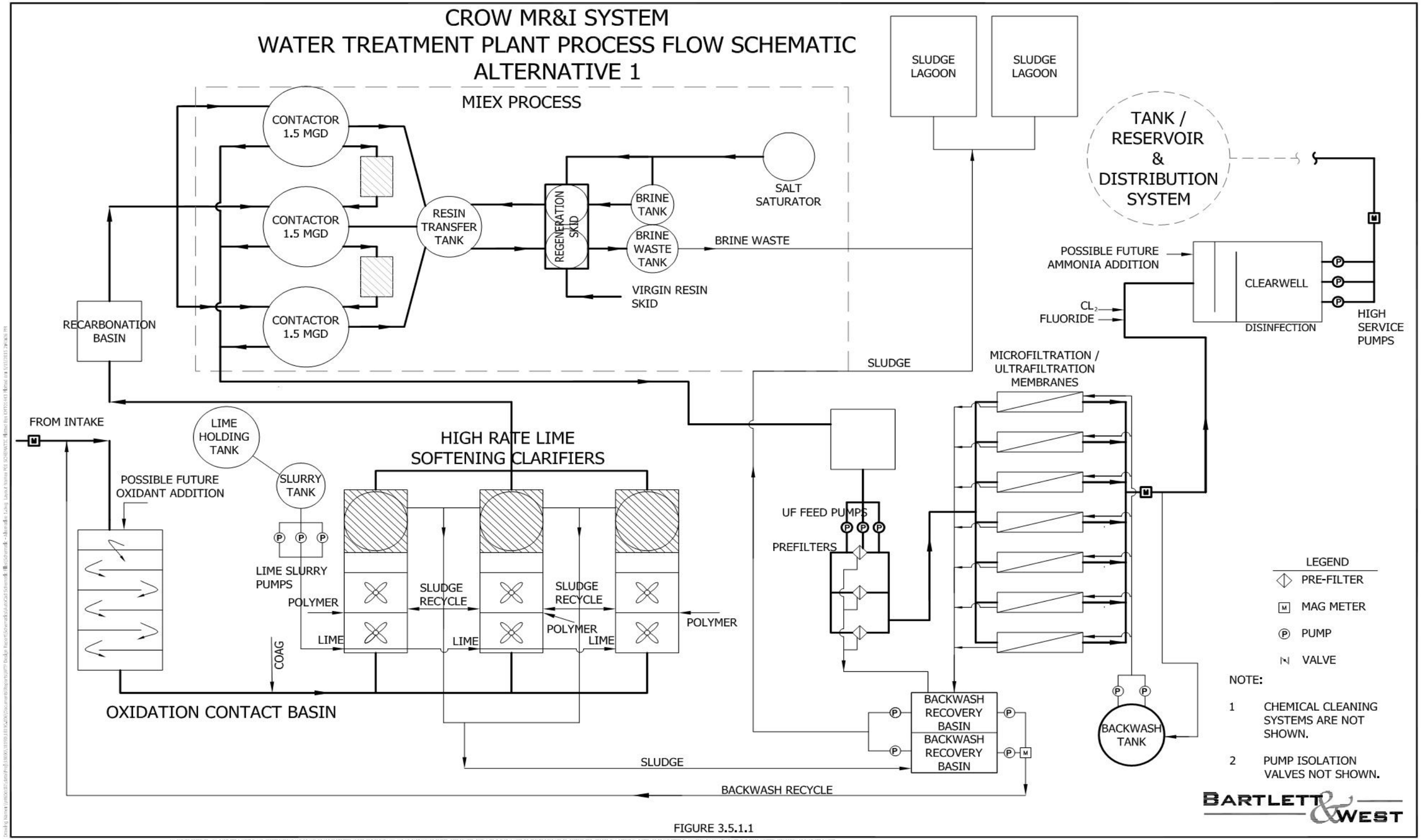

FIGURE 3.5.1.1

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CROW MR&I SYSTEM
WATER TREATMENT PLANT PROCESS FLOW SCHEMATIC
ALTERNATIVE 2

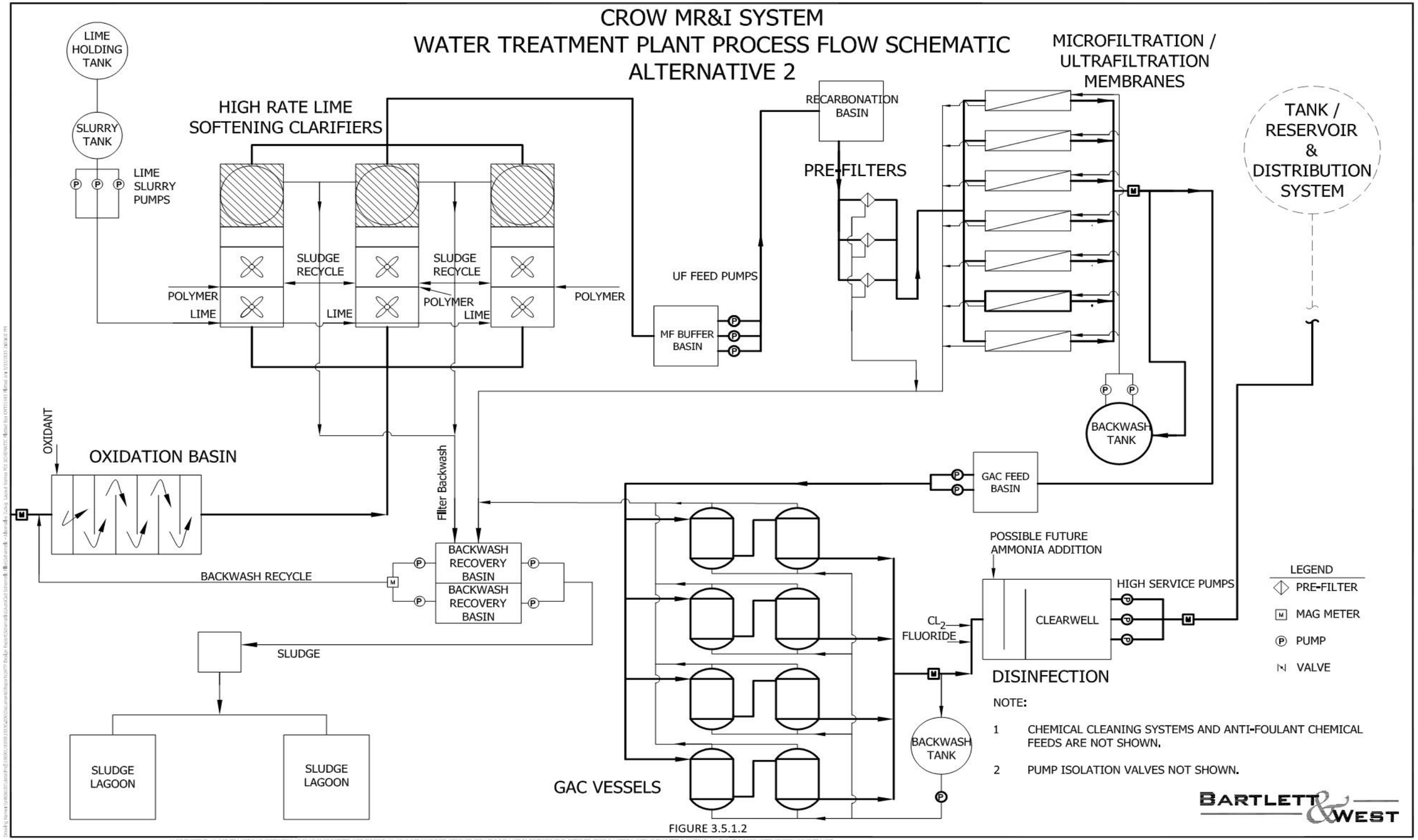

FIGURE 3.5.1.2

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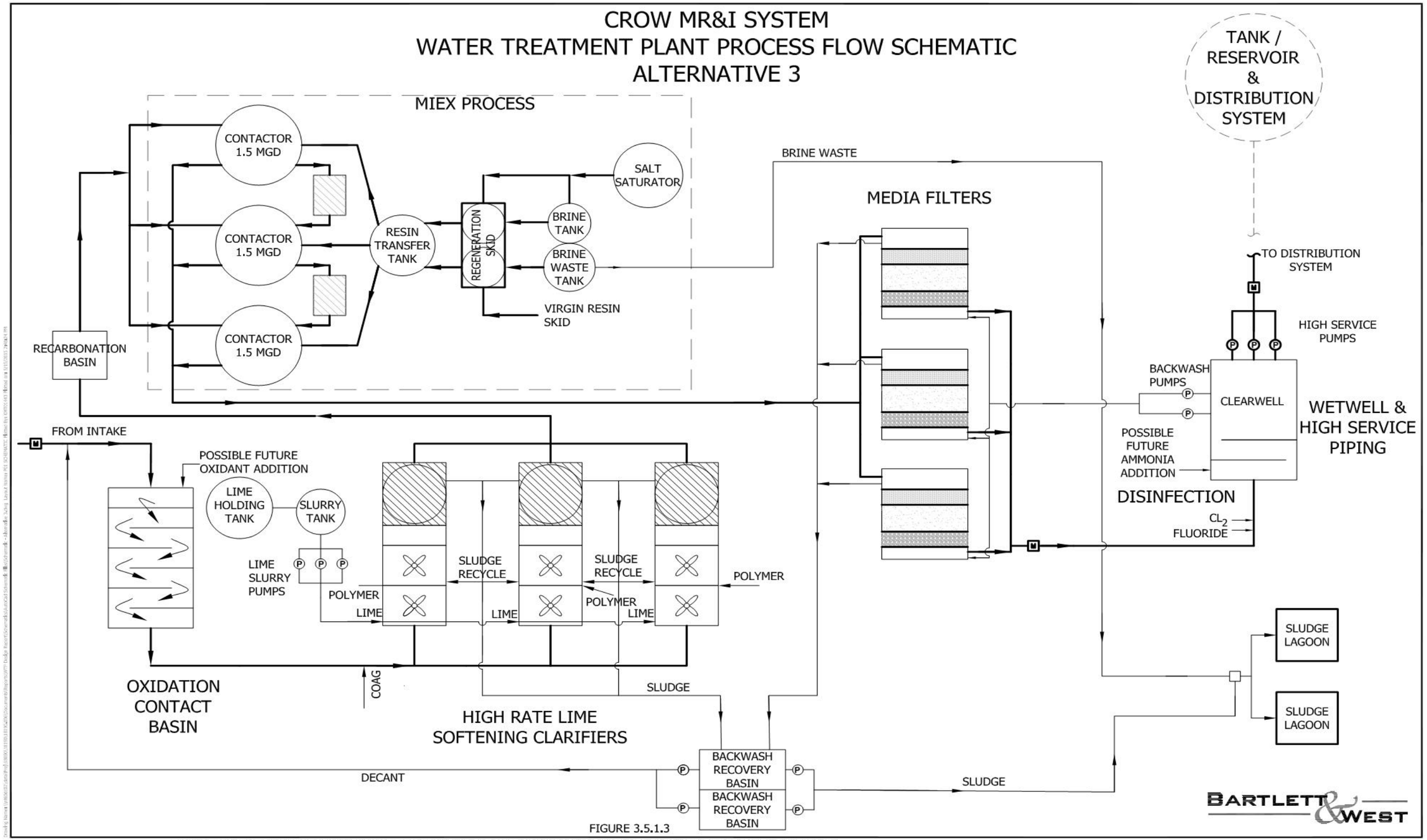

CROW MR&I SYSTEM
WATER TREATMENT PLANT PROCESS FLOW SCHEMATIC
ALTERNATIVE 3
MIEX PROCESS
CONTACTOR 1.5 MGD
CONTACTOR 1.5 MGD
CONTACTOR 1.5 MGD
RESIN TRANSFER TANK
REGENERATION SKID
BRINE TANK
BRINE WASTE TANK
SALT SATURATOR
VIRGIN RESIN SKID
RECARBONATION BASIN
BRINE WASTE
MEDIA FILTERS
TANK / RESERVOIR & DISTRIBUTION SYSTEM
TO DISTRIBUTION SYSTEM
HIGH SERVICE PUMPS
BACKWASH PUMPS
CLEARWELL
WETWELL & HIGH SERVICE PIPING
POSSIBLE FUTURE AMMONIA ADDITION
DISINFECTION
CL_2
FLUORIDE
FROM INTAKE
POSSIBLE FUTURE OXIDANT ADDITION
LIME HOLDING TANK
SLURRY TANK
LIME SLURRY PUMPS
POLYMER
LIME
SLUDGE RECYCLE
SLUDGE RECYCLE
POLYMER
LIME
LIME
POLYMER
OXIDATION CONTACT BASIN
COAG
SLUDGE
HIGH RATE LIME SOFTENING CLARIFIERS
SLUDGE LAGOON
SLUDGE LAGOON
DECANT
BACKWASH RECOVERY BASIN
BACKWASH RECOVERY BASIN
SLUDGE
BARTLETT & WEST

FIGURE 3.5.1.3

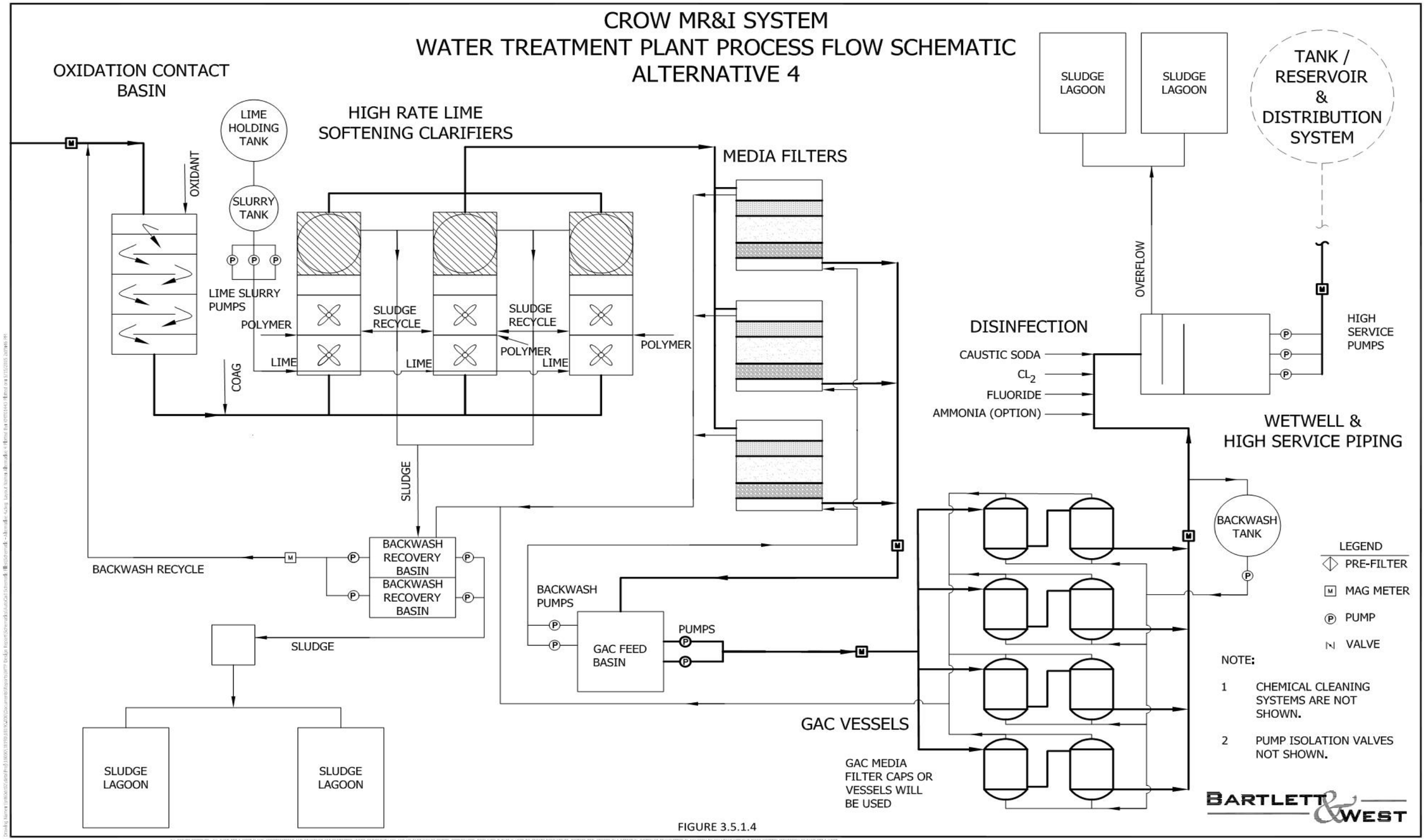
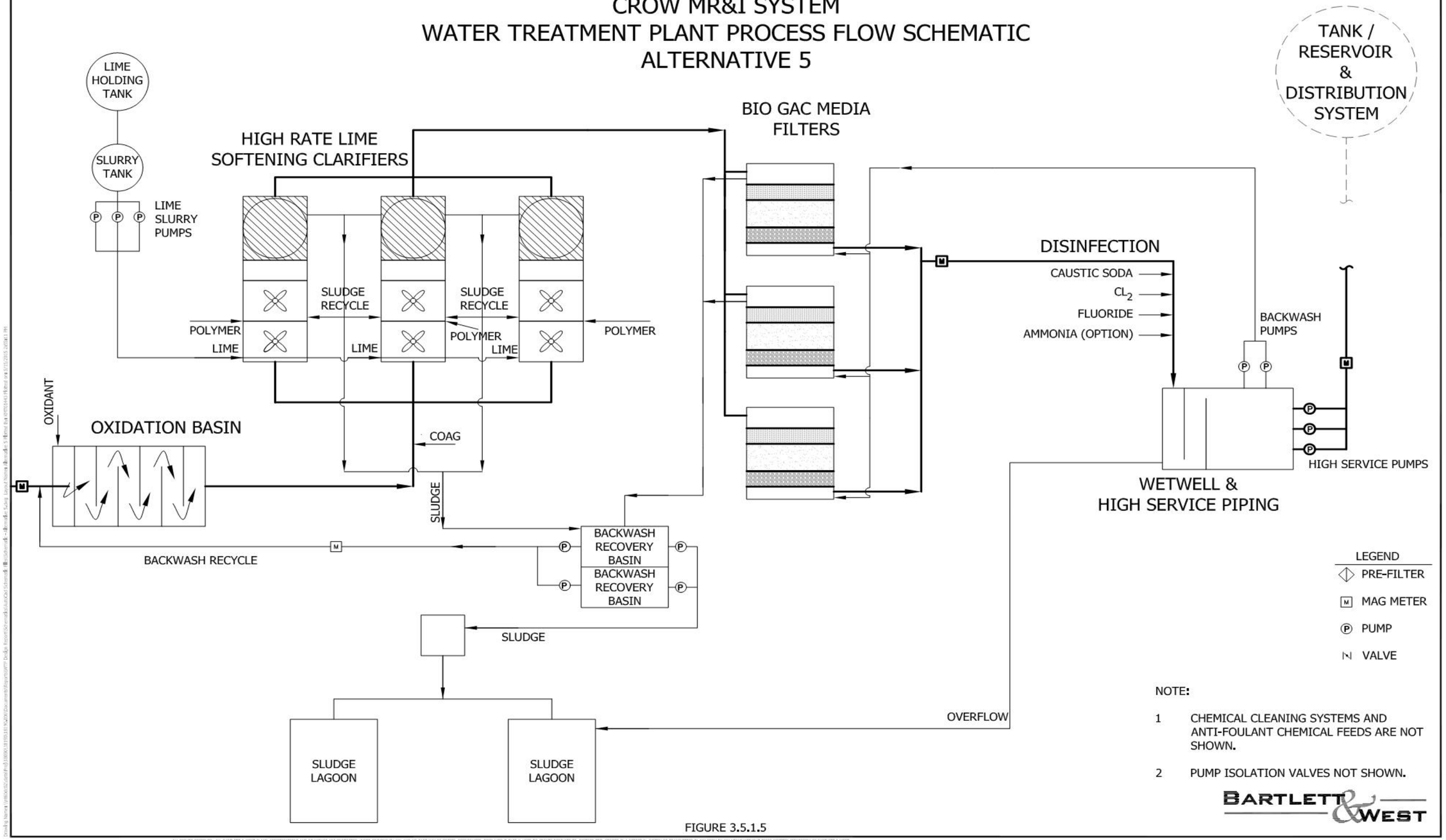

CROW MR&I SYSTEM
WATER TREATMENT PLANT PROCESS FLOW SCHEMATIC
ALTERNATIVE 4
OXIDATION CONTACT BASIN
OXIDANT
LIME HOLDING TANK
SLURRY TANK
LIME SLURRY PUMPS
HIGH RATE LIME SOFTENING CLARIFIERS
POLYMER
LIME
SLUDGE RECYCLE
COAG
SLUDGE
MEDIA FILTERS
BACKWASH RECOVERY BASIN
BACKWASH RECOVERY BASIN
BACKWASH RECYCLE
SLUDGE
SLUDGE LAGOON
SLUDGE LAGOON
BACKWASH PUMPS
GAC FEED BASIN
PUMPS
GAC VESSELS
GAC MEDIA FILTER CAPS OR VESSELS WILL BE USED
SLUDGE LAGOON
SLUDGE LAGOON
TANK / RESERVOIR & DISTRIBUTION SYSTEM
OVERFLOW
DISINFECTION
CAUSTIC SODA
CL_2
FLUORIDE
AMMONIA (OPTION)
HIGH SERVICE PUMPS
WETWELL & HIGH SERVICE PIPING
BACKWASH TANK
LEGEND
PRE-FILTER
MAG METER
PUMP
VALVE
NOTE:
1 CHEMICAL CLEANING SYSTEMS ARE NOT SHOWN.
2 PUMP ISOLATION VALVES NOT SHOWN.
BARTLETT & WEST

FIGURE 3.5.1.4

CROW MR&I SYSTEM
WATER TREATMENT PLANT PROCESS FLOW SCHEMATIC
ALTERNATIVE 5



NOTE:

1 CHEMICAL CLEANING SYSTEMS AND ANTI-FOULANT CHEMICAL FEEDS ARE NOT SHOWN.

2 PUMP ISOLATION VALVES NOT SHOWN.

BARTLETT & WEST

FIGURE 3.5.1.5

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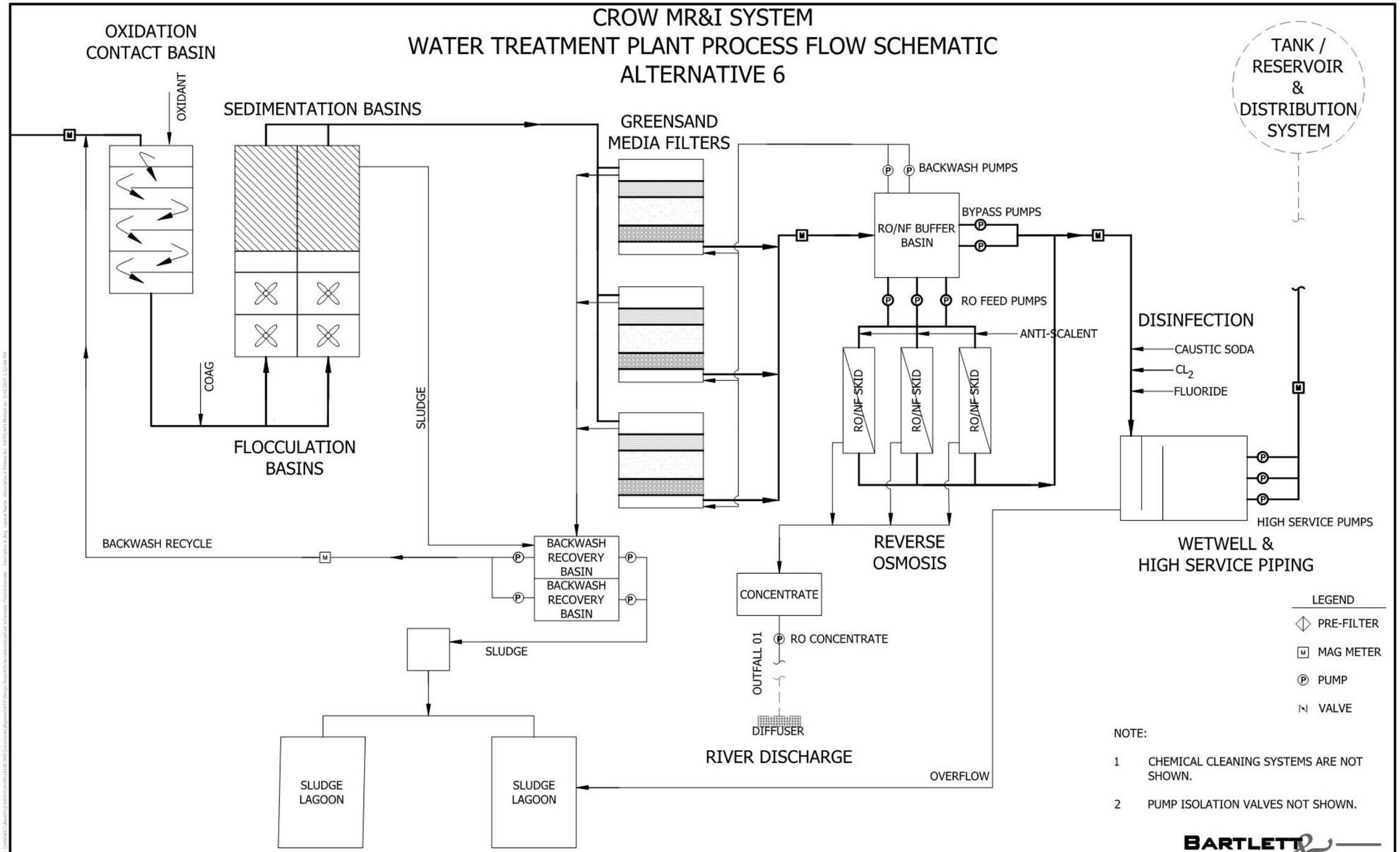
CROW MR&I SYSTEM
WATER TREATMENT PLANT PROCESS FLOW SCHEMATIC
ALTERNATIVE 6



NOTE:

1 CHEMICAL CLEANING SYSTEMS ARE NOT SHOWN.

2 PUMP ISOLATION VALVES NOT SHOWN.

BARTLETT & WEST

FIGURE 3.5.1.6

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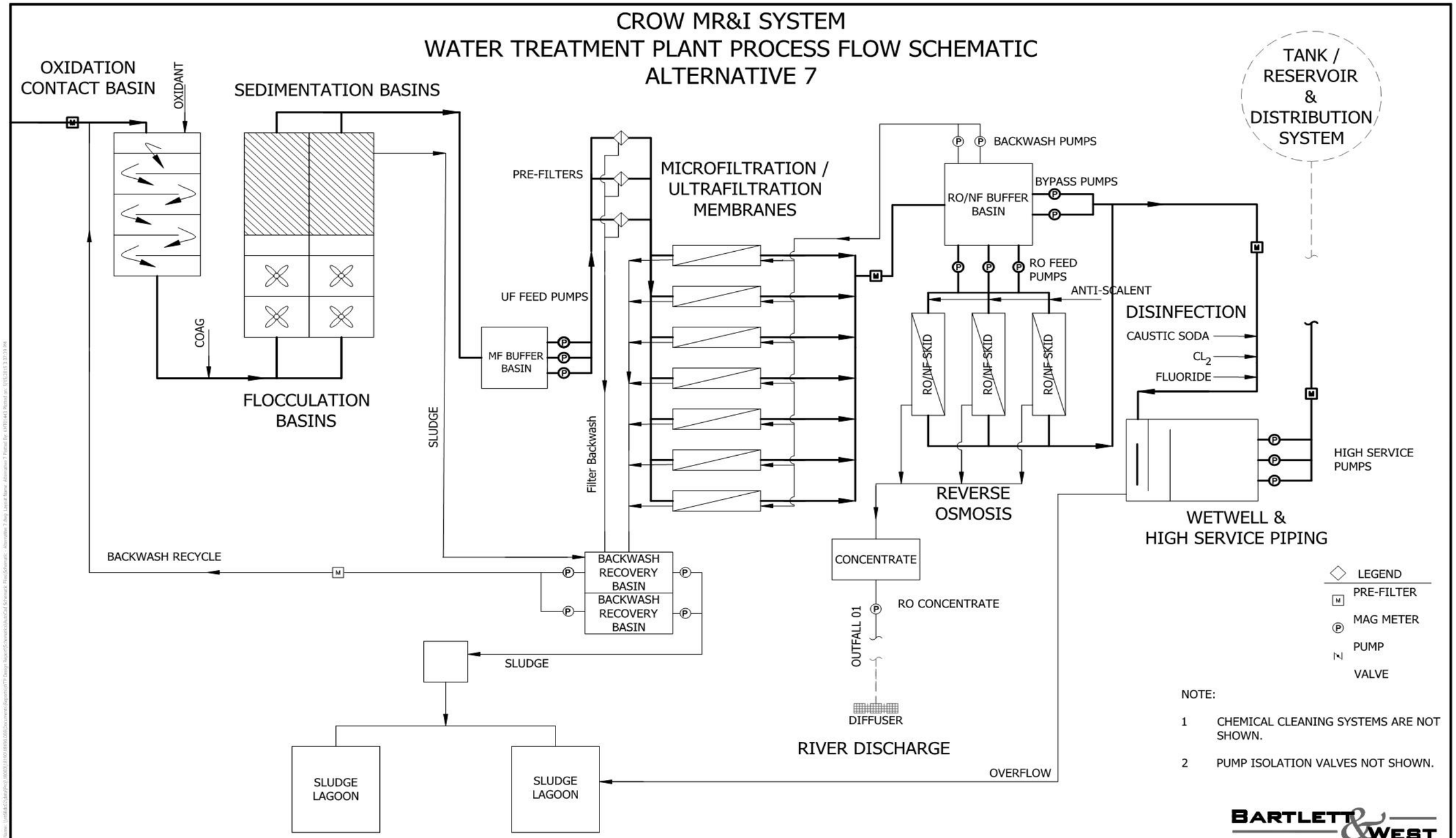

FIGURE 3.5.1.7

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3.5.2 Treatment Train Mass Balance Diagrams

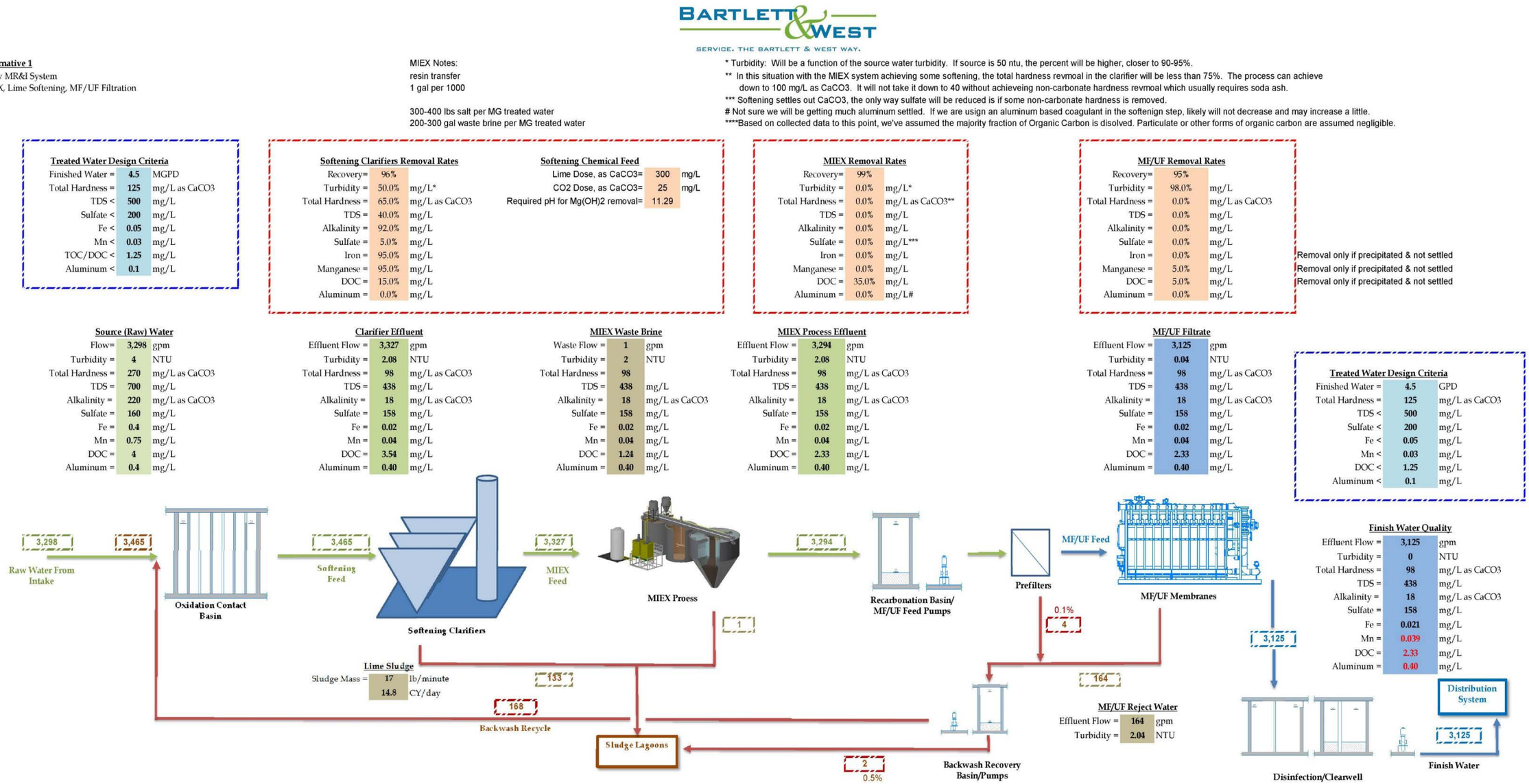


Figure 3.5.2.1 - Alternative Train No. 1 - Pretreatment Oxidation, MIEX Pretreatment, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Micro/Ultra Filtration; Chlorine

Alternative 2
Crow MR&I System
Softening, Membrane Filtration, GAC

Treated Water Design Criteria

Finished Water =	4.5	MGD
Total Hardness =	125	mg/L as CaCO3
TDS <	500	mg/L
Sulfate <	200	mg/L
Fe <	0.05	mg/L
Mn <	0.03	mg/L
TOC/DOC <	1.25	mg/L
Aluminum <	0.1	mg/L

Source (Raw) Water

Turbidity =	4	NTU
Total Hardness =	270	mg/L as CaCO3
TDS =	700	mg/L
Alkalinity =	220	mg/L as CaCO3
Sulfate =	160	mg/L
Fe =	0.4	mg/L
Mn =	0.75	mg/L
DOC =	4	mg/L
Aluminum =	0.4	mg/L

Softening Removal

Recovery=	96%	
Turbidity =	65.0%	mg/L
Total Hardness =	65.0%	mg/L as CaCO3
TDS =	40.0%	mg/L
Alkalinity =	0.0%	mg/L
Sulfate =	5.0%	mg/L
Iron =	95.0%	mg/L
Manganese =	95.0%	mg/L
DOC =	20.0%	mg/L
Aluminum =	0.0%	mg/L

Softening Chemical Feed

Lime Dose, as CaCO3=	300	mg/L
CO2 Dose, as CaCO3=	25	mg/L
Required pH for Mg(OH)2 removal=	11.29	

Clarifier Effluent

Effluent Flow =	3,326	gpm
Turbidity =	1.46	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	220	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
DOC =	3.33	mg/L
Aluminum =	0.40	mg/L

MF/UF Removal Rates (Typical)

Recovery=	95%	
Turbidity =	95.0%	mg/L
Total Hardness =	0.0%	mg/L as CaCO3
TDS =	0.0%	mg/L
Alkalinity =	0.0%	mg/L
Sulfate =	0.0%	mg/L
Iron =	0.0%	mg/L
Manganese =	5.0%	mg/L
DOC =	0.0%	mg/L
Aluminum =	0.0%	mg/L

MF/UF Membrane Filtrate

Effluent Flow =	3,157	gpm
Turbidity =	0.08	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	220	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
DOC =	3.33	mg/L
Aluminum =	0.40	mg/L

GAC Removal Rates (Typical)

Recovery=	99%	
Turbidity =	0.0%	mg/L
Total Hardness =	0.0%	mg/L as CaCO3
TDS =	0.0%	mg/L
Alkalinity =	0.0%	mg/L
Sulfate =	0.0%	mg/L
Iron =	0.0%	mg/L
Manganese =	0.0%	mg/L
DOC =	70.0%	mg/L
Aluminum =	0.0%	mg/L

GAC Filtrate

Effluent Flow =	3,125	gpm
Turbidity =	0.08	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	220	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
DOC =	1.01	mg/L
Aluminum =	0.40	mg/L

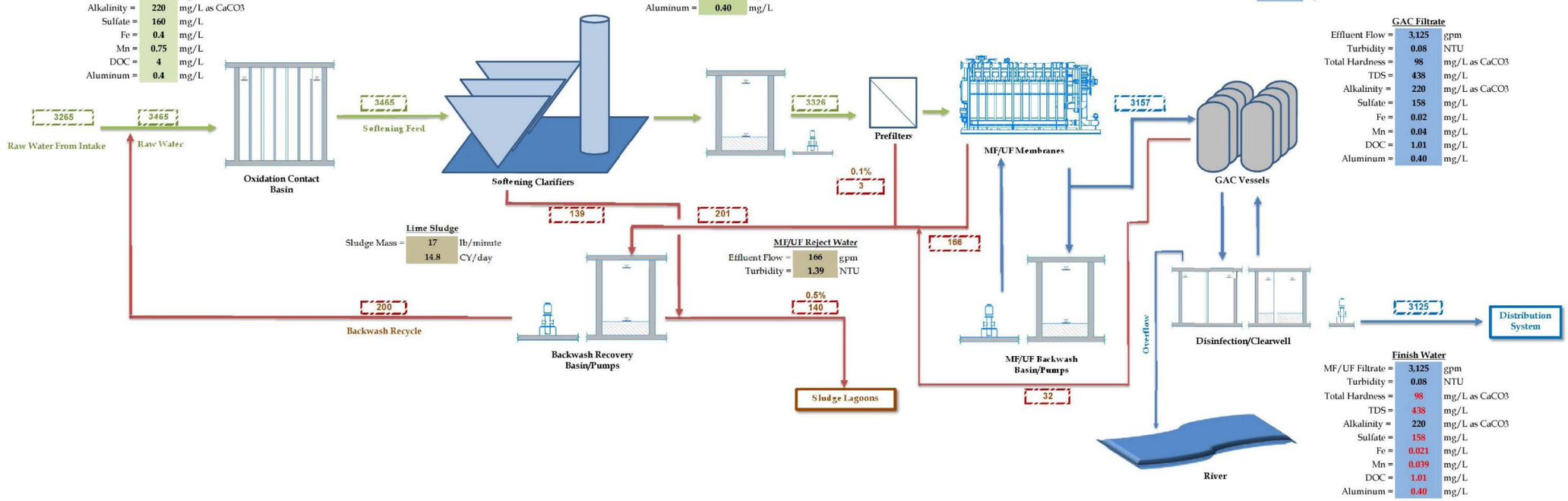


Figure 3.5.2.2 - Alternative Train No. 2 - Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation)Micro/Ultra Filtration; GAC Vessels, Chlorine

Alternative 3

Crow MR&I System

MIEX, Lime Softening, MF/UF Filtration

Treated Water Design Criteria

Finished Water =	4.5	MGD
Total Hardness =	125	mg/L as CaCO3
TDS <	500	mg/L
Sulfate <	200	mg/L
Fe <	0.05	mg/L
Mn <	0.03	mg/L
TOC <	1.25	mg/L
Aluminum <	0.1	mg/L

Sofening Clarifier Removal Rates

Recovery=	96%	
Turbidity =	50.0%	mg/L
Total Hardness =	65.0%	mg/L as CaCO3
TDS =	40.0%	mg/L
Alkalinity =	92.0%	mg/L
Sulfate =	5.0%	mg/L
Iron =	95.0%	mg/L
Manganese =	95.0%	mg/L
DOC =	15.0%	mg/L
Aluminum =	0.0%	mg/L

Softening Chemical Feed

Lime Dose, as CaCO3=	300	mg/L
CO2 Dose, as CaCO3=	25	mg/L
Required pH for Mg(OH)2 removal=	11.29	

MIEX Removal Rates

Recovery=	99%	
Turbidity =	0.0%	mg/L
Total Hardness =	0.0%	mg/L as CaCO3
TDS =	0.0%	mg/L
Alkalinity =	0.0%	mg/L
Sulfate =	0.0%	mg/L
Iron =	0.0%	mg/L
Manganese =	0.0%	mg/L
DOC =	35.0%	mg/L
Aluminum =	0.0%	mg/L

Media Filter Removal Rates

Recovery=	95%	
Turbidity =	90.0%	mg/L
Total Hardness =	0.0%	mg/L as CaCO3
TDS =	0.0%	mg/L
Alkalinity =	0.0%	mg/L
Sulfate =	0.0%	mg/L
Iron =	0.0%	mg/L
Manganese =	5.0%	mg/L
DOC =	0.0%	mg/L
Aluminum =	0.0%	mg/L

Source (Raw) Water

Flow=	3,297	gpm
Turbidity =	4	NTU
Total Hardness =	270	mg/L as CaCO3
TDS =	700	mg/L
Alkalinity =	220	mg/L as CaCO3
Sulfate =	160	mg/L
Fe =	0.4	mg/L
Mn =	0.75	mg/L
DOC =	4.00	mg/L
Aluminum =	0.4	mg/L

Clarifier Effluent

Effluent Flow =	3,323	gpm
Turbidity =	2	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	18	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
DOC =	3.54	mg/L
Aluminum =	0.40	mg/L

MIEX Waste Brine

Effluent Flow =	1	gpm
Turbidity =	2.08	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	18	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
DOC =	0.60	mg/L
Aluminum =	0.40	mg/L

MIEX Effluent

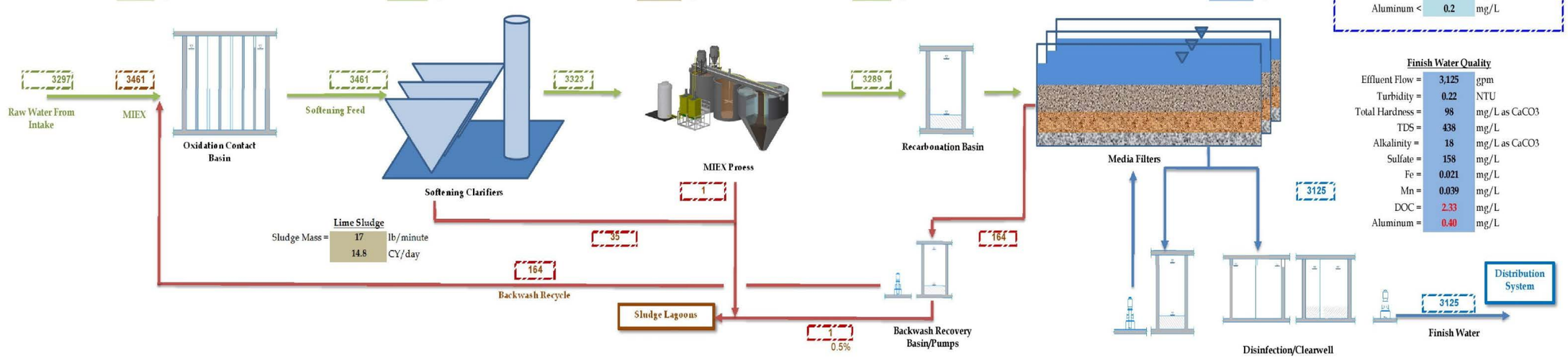
Effluent Flow =	3,289	gpm
Turbidity =	2	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	18	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
DOC =	2.33	mg/L
Aluminum =	0.40	mg/L

Media Filtrate

Effluent Flow =	3,125	gpm
Turbidity =	0.22	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	18	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
DOC =	2.33	mg/L
Aluminum =	0.40	mg/L

Treated Water Design Criteria

Finished Water =	4.5	GPD
Total Hardness =	125	mg/L as CaCO3
TDS <	500	mg/L
Sulfate <	250	mg/L
Fe <	0.3	mg/L
Mn <	0.05	mg/L
TOC <	1.5	mg/L
Aluminum <	0.2	mg/L



Lime Sludge

Sludge Mass =	17	lb/minute
	14.8	CY/day

Finish Water Quality

Effluent Flow =	3,125	gpm
Turbidity =	0.22	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	18	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.021	mg/L
Mn =	0.039	mg/L
DOC =	2.33	mg/L
Aluminum =	0.40	mg/L

Figure 3.5.2.3 - Alternative Train No. 3 - Pretreatment Oxidation, MIEX Pretreatment, Lime Softening Clarification (including Flocculation, Coagulation, and Sedimentation); Media Filtration; Chlorine

Alternative 4
Crow MR&I System
Softening, Media Filtration, GAC

Treated Water Design Criteria

Finished Water =	4.5	MGD
Total Hardness =	125	mg/L as CaCO3
TDS <	500	mg/L
Sulfate <	200	mg/L
Fe <	0.05	mg/L
Mn <	0.03	mg/L
TOC <	1.25	mg/L
Aluminum <	0.1	mg/L

Softening Removal

Recovery=	96%	
Turbidity =	50.0%	mg/L
Total Hardness =	65.0%	mg/L as CaCO3
TDS =	40.0%	mg/L
Alkalinity =	92.0%	mg/L
Sulfate =	5.0%	mg/L
Iron =	95.0%	mg/L
Manganese =	95.0%	mg/L
TOC =	15.0%	mg/L
Aluminum =	0.0%	mg/L

Softening Chemical Feed mg/L

Lime Dose, as CaCO3=	300	mg/L
CO2 Dose, as CaCO3=	25	
Required pH for Mg(OH)2 removal=	11.29	

Media Removal Rates (Typical)

Recovery=	90%	
Turbidity =	90.0%	mg/L
Total Hardness =	0.0%	mg/L as CaCO3
TDS =	0.0%	mg/L
Alkalinity =	0.0%	mg/L
Sulfate =	0.0%	mg/L
Iron =	0.0%	mg/L
Manganese =	5.0%	mg/L
TOC =	0.0%	mg/L
Aluminum =	0.0%	mg/L

GAC Removal Rates (Typical)

Recovery=	99%	
Turbidity =	0.0%	mg/L
Total Hardness =	0.0%	mg/L as CaCO3
TDS =	0.0%	mg/L
Alkalinity =	0.0%	mg/L
Sulfate =	0.0%	mg/L
Iron =	0.0%	mg/L
Manganese =	0.0%	mg/L
TOC =	65.0%	mg/L
Aluminum =	0.0%	mg/L

Source (Raw) Water

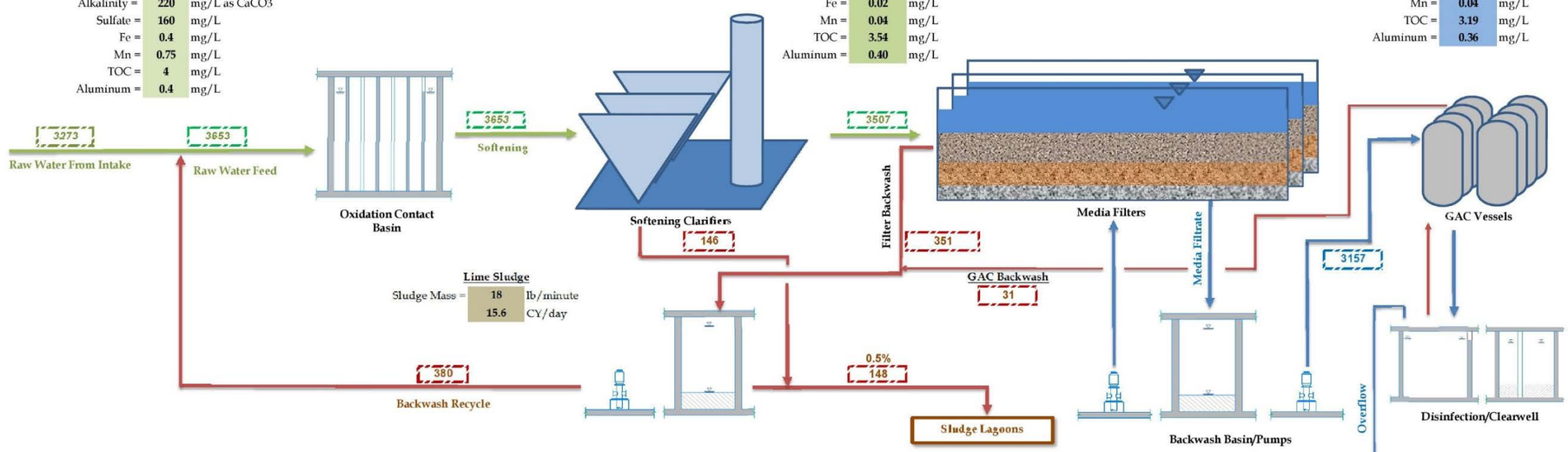
Turbidity =	4	NTU
Total Hardness =	270	mg/L as CaCO3
TDS =	700	mg/L
Alkalinity =	220	mg/L as CaCO3
Sulfate =	160	mg/L
Fe =	0.4	mg/L
Mn =	0.75	mg/L
TOC =	4	mg/L
Aluminum =	0.4	mg/L

Clarifier Effluent

Effluent Flow =	3,507	gpm
Turbidity =	2.08	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	18	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
TOC =	3.54	mg/L
Aluminum =	0.40	mg/L

Media Filtrate

Effluent Flow =	3,157	gpm
Turbidity =	0.21	NTU
Total Hardness =	89	mg/L as CaCO3
TDS =	394	mg/L
Alkalinity =	17	mg/L as CaCO3
Sulfate =	143	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
TOC =	3.19	mg/L
Aluminum =	0.36	mg/L



Lime Sludge

Sludge Mass =	18	lb/minute
	15.6	CY/day

GAC Filtrate

Effluent Flow =	3,125	gpm
Turbidity =	0.21	NTU
Total Hardness =	89	mg/L as CaCO3
TDS =	394	mg/L
Alkalinity =	17	mg/L as CaCO3
Sulfate =	143	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
TOC =	1.13	mg/L
Aluminum =	0.36	mg/L

Finish Water

Effluent Flow =	3,125	gpm
Turbidity =	0	NTU
Total Hardness =	89	mg/L as CaCO3
TDS =	394	mg/L
Alkalinity =	17	mg/L as CaCO3
Sulfate =	143	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
TOC =	1.13	mg/L
Aluminum =	0.36	mg/L

Figure 3.5.2.4 - Alternative Train No. 4 - Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, and Sedimentation); Media Filtration; GAC Vessels, Chlorine

Alternative 5
Crow MR&I System
Softening, Bio/GAC Media Filtration

Treated Water Design Criteria

Finished Water =	4.5	MGD
Total Hardness =	125	mg/L as CaCO3
TDS <	500	mg/L
Sulfate <	200	mg/L
Fe <	0.05	mg/L
Mn <	0.03	mg/L
TOC <	1.25	mg/L
Aluminum <	0.1	mg/L

Softening Removal Rates

Recovery=	96%	
Turbidity =	65.0%	mg/L
Total Hardness =	65.0%	mg/L as CaCO3
TDS =	40.0%	mg/L
Alkalinity =	0.0%	mg/L
Sulfate =	5.0%	mg/L
Iron =	95.0%	mg/L
Manganese =	95.0%	mg/L
TOC =	20.0%	mg/L
Aluminum =	0.0%	mg/L

Softening Chemical Feed

Lime Dose, as CaCO3=	300	mg/L
CO2 Dose, as CaCO3=	25	mg/L
Required pH for Mg(OH)2 removal=	11.29	

Bio GAC Media Filter Removal Rates

Recovery=	95%	
Turbidity =	90.0%	mg/L
Total Hardness =	0.0%	mg/L as CaCO3
TDS =	0.0%	mg/L
Alkalinity =	0.0%	mg/L
Sulfate =	0.0%	mg/L
Iron =	0.0%	mg/L
Manganese =	5.0%	mg/L
TOC =	40.0%	mg/L
Aluminum =	0.0%	mg/L

10% From Chance V. Lauderdale, 2011
see process alternate spreadsheet for 40% reference

Source (Raw) Water

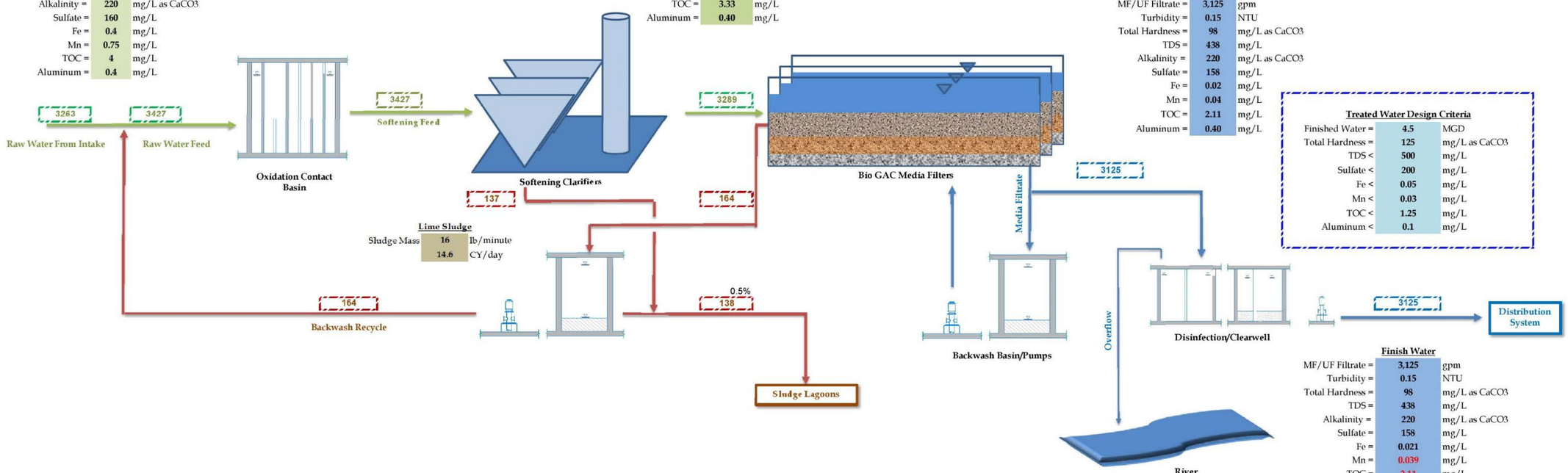
Turbidity =	4	NTU
Total Hardness =	270	mg/L as CaCO3
TDS =	700	mg/L
Alkalinity =	220	mg/L as CaCO3
Sulfate =	160	mg/L
Fe =	0.4	mg/L
Mn =	0.75	mg/L
TOC =	4	mg/L
Aluminum =	0.4	mg/L

Clarifier Effluent

MF/UF Filtrate =	3,289	gpm
Turbidity =	1.46	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	220	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
TOC =	3.33	mg/L
Aluminum =	0.40	mg/L

Bio GAC Media Filtrate

MF/UF Filtrate =	3,125	gpm
Turbidity =	0.15	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	220	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.02	mg/L
Mn =	0.04	mg/L
TOC =	2.11	mg/L
Aluminum =	0.40	mg/L



Treated Water Design Criteria

Finished Water =	4.5	MGD
Total Hardness =	125	mg/L as CaCO3
TDS <	500	mg/L
Sulfate <	200	mg/L
Fe <	0.05	mg/L
Mn <	0.03	mg/L
TOC <	1.25	mg/L
Aluminum <	0.1	mg/L

Finish Water

MF/UF Filtrate =	3,125	gpm
Turbidity =	0.15	NTU
Total Hardness =	98	mg/L as CaCO3
TDS =	438	mg/L
Alkalinity =	220	mg/L as CaCO3
Sulfate =	158	mg/L
Fe =	0.021	mg/L
Mn =	0.039	mg/L
TOC =	2.11	mg/L
Aluminum =	0.40	mg/L

Figure 3.5.2.5 - Alternative Train No. 5 - Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Bio GAC Media Filtration, Chlorine

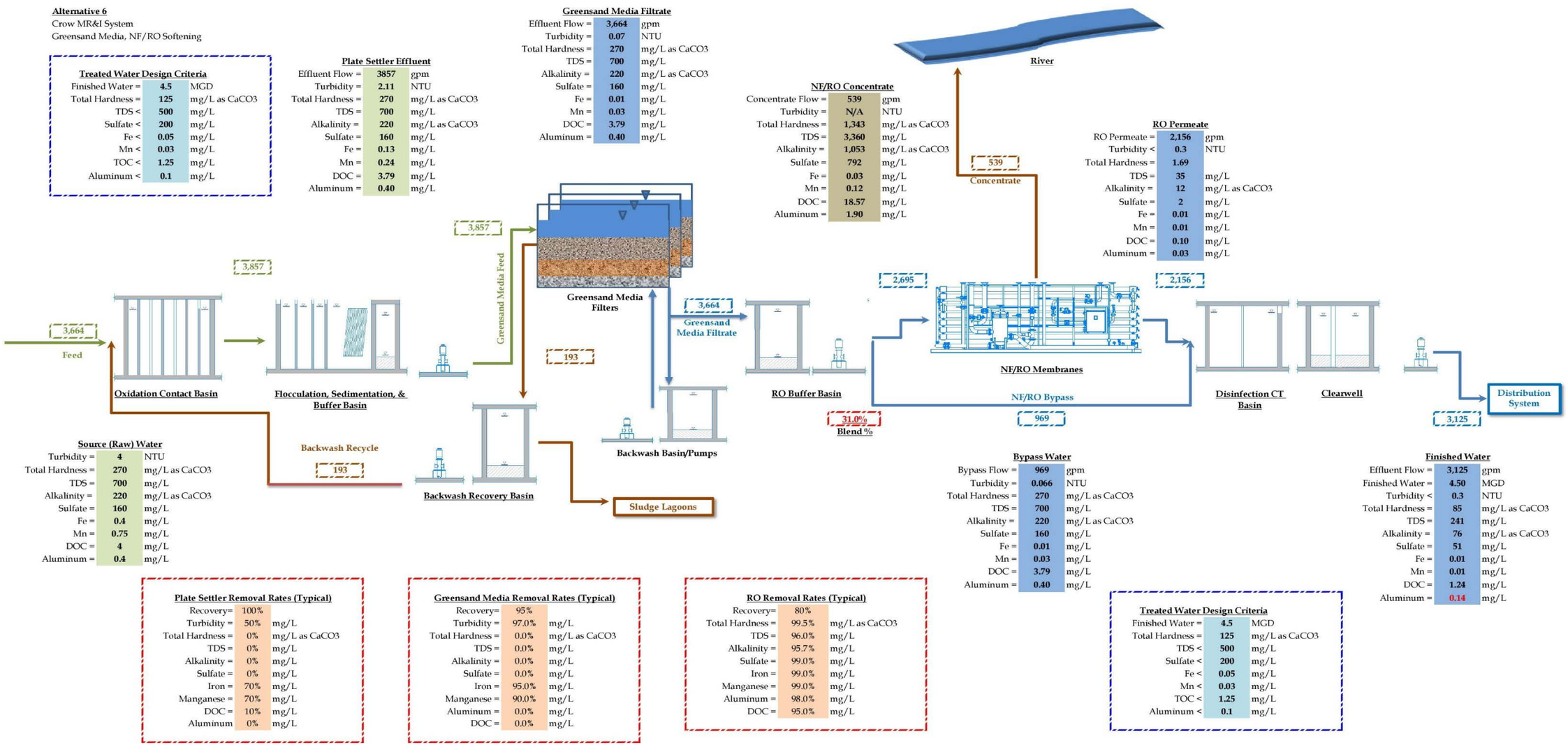


Figure 3.5.2.6 - Alternative Train No. 6 - (Pretreatment Oxidation, Coagulation, Sedimentation) Greensand Media Filtration; NF/RO Softening, Chlorine

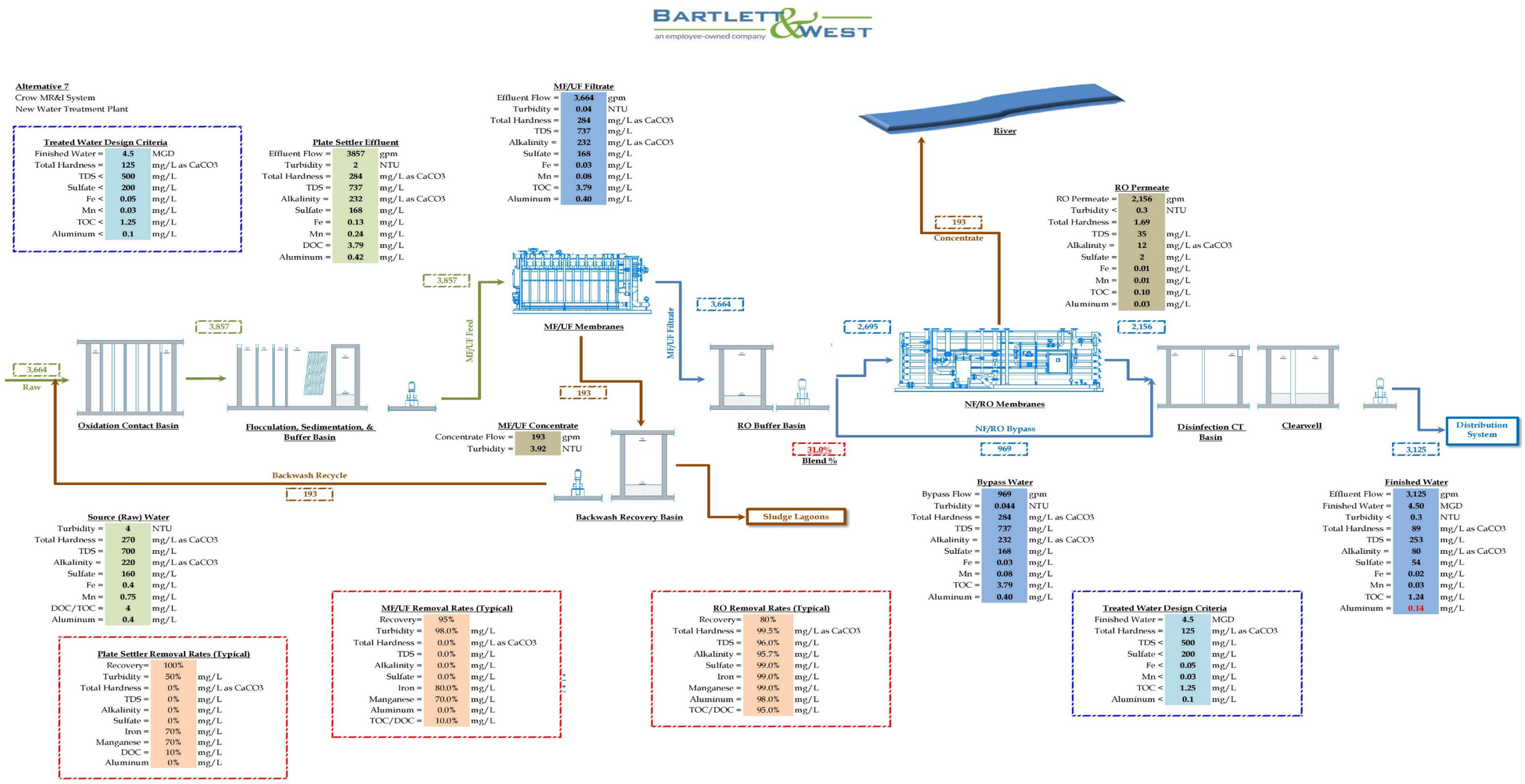


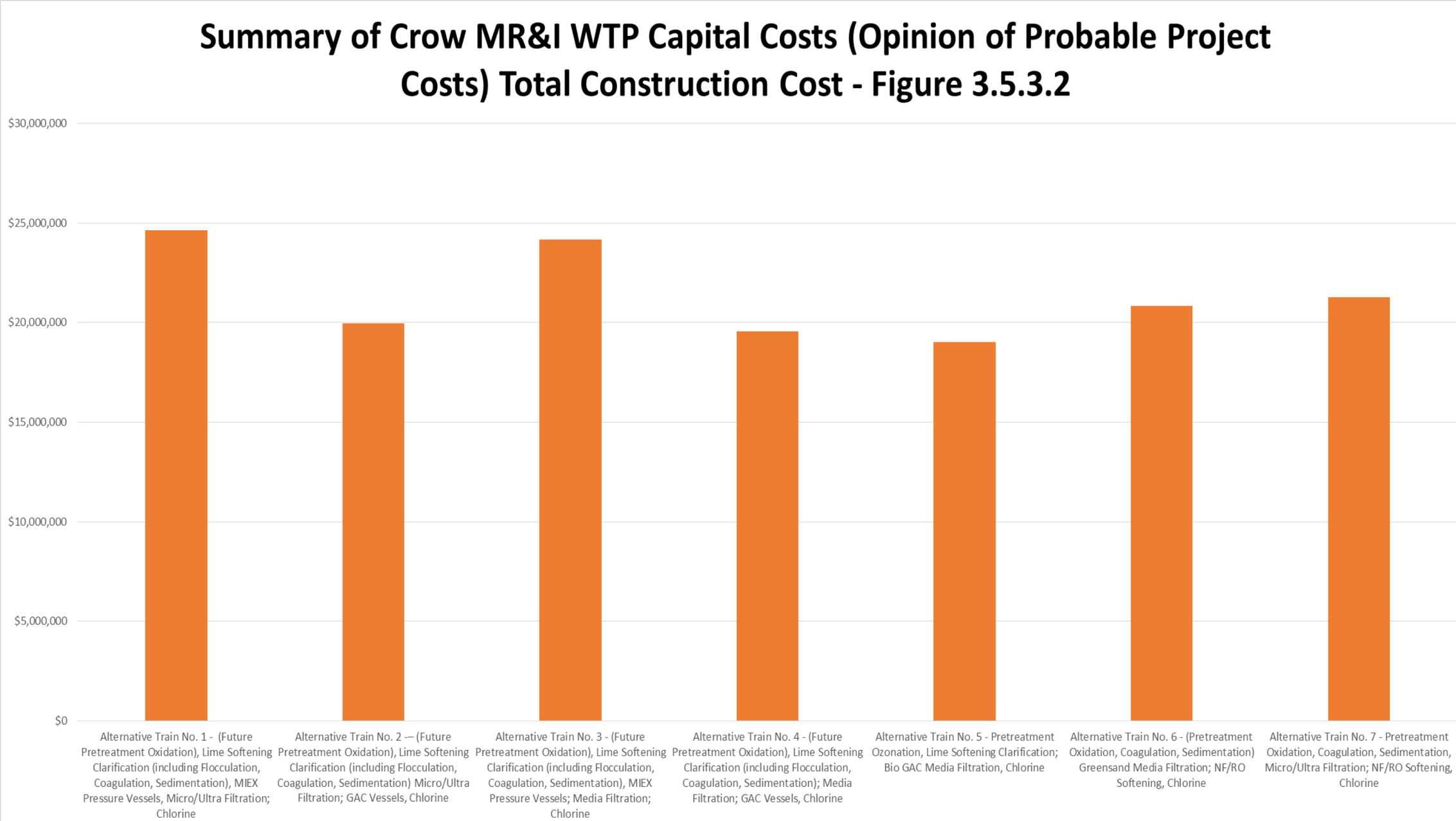
Figure 3.5.2.7 - Alternative Train No. 7 - Pretreatment Oxidation, Coagulation, Sedimentation, Micro/Ultra Filtration; NF/RO Softening, Chlorine

3.5.3 Treatment Train Cost Estimates-Capital and OM&R

The below table provides a summary of the estimated Capital Costs of the options considered. Complete breakdown of the estimates are include in Appendix E. These costs will be re-evaluated upon the completion of all planned bench and pilot testing. Based on the design and planning level of this report (Feasibility) it is estimated that these costs are accurate to approximately 15-20% +/-.

Summary of Crow MR&I WTP Capital Costs (Opinion of Probable Project Costs)	**Figure 3.5.3.1**
Treatment Train Alternative Descriptions	**Total Construction Cost**
Alternative Train No. 1 - (Future Pretreatment Oxidation), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels, Micro/Ultra Filtration; Chlorine	$24,633,000
Alternative Train No. 2 -– (Future Pretreatment Oxidation), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation) Micro/Ultra Filtration; GAC Vessels, Chlorine	$19,975,500
Alternative Train No. 3 - (Future Pretreatment Oxidation), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels; Media Filtration; Chlorine	$24,167,250
Alternative Train No. 4 - (Future Pretreatment Oxidation), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Media Filtration; GAC Vessels, Chlorine	$19,551,150
Alternative Train No. 5 - Pretreatment Ozonation, Lime Softening Clarification; Bio GAC Media Filtration, Chlorine	$19,033,650
Alternative Train No. 6 - (Pretreatment Oxidation, Coagulation, Sedimentation) Greensand Media Filtration; NF/RO Softening, Chlorine	$20,824,200
Alternative Train No. 7 - Pretreatment Oxidation, Coagulation, Sedimentation, Micro/Ultra Filtration; NF/RO Softening, Chlorine	$21,279,600

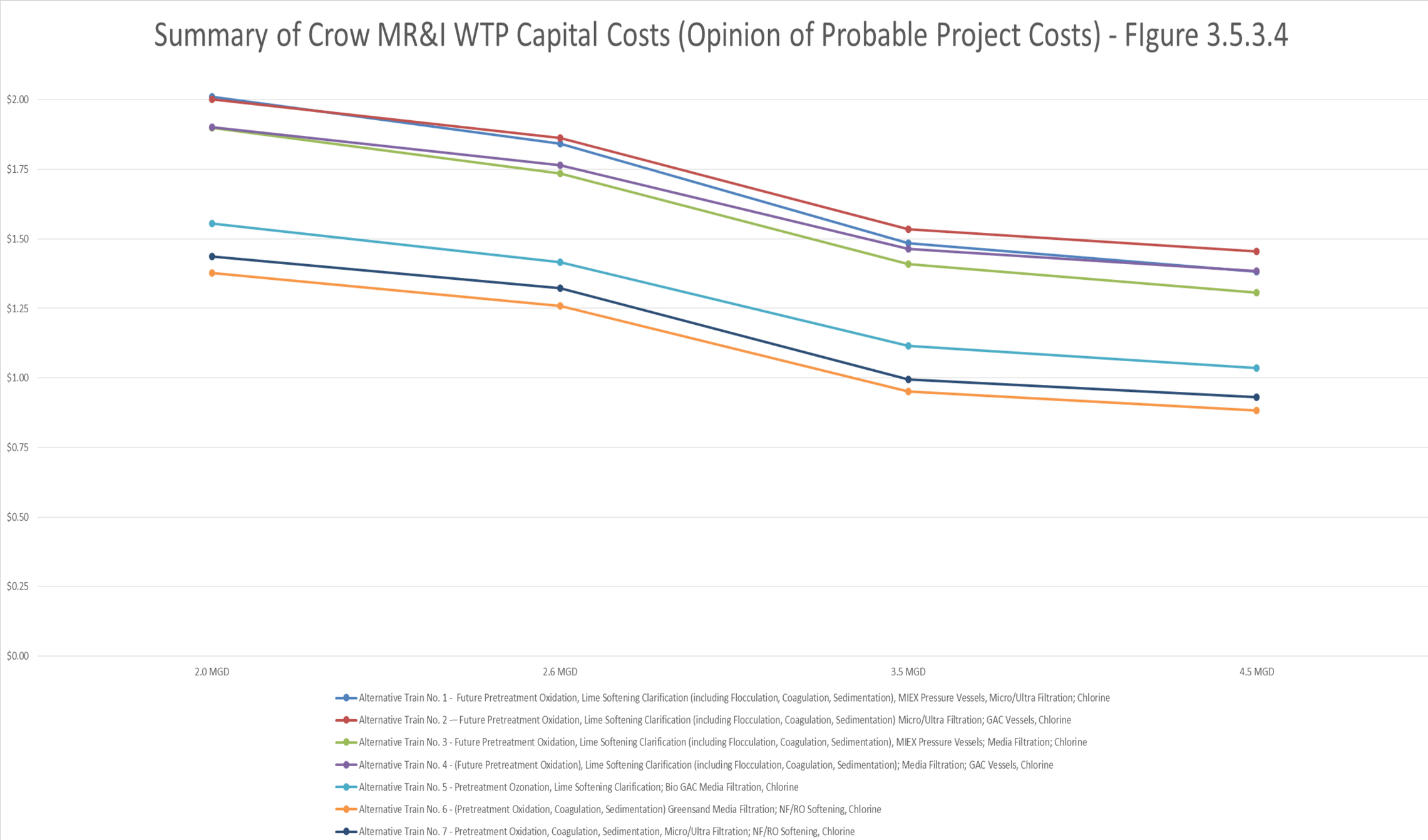
Figure 3.5.3.1 - Alternatives Capital Cost Estimate Table


Summary of Crow MR&I WTP Capital Costs (Opinion of Probable Project Costs) Total Construction Cost - Figure 3.5.3.2
$30,000,000
$25,000,000
$20,000,000
$15,000,000
$10,000,000
$5,000,000
$0
Alternative Train No. 1 - (Future Pretreatment Oxidation), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels, Micro/Ultra Filtration; Chlorine
Alternative Train No. 2 -– (Future Pretreatment Oxidation), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation) Micro/Ultra Filtration; GAC Vessels, Chlorine
Alternative Train No. 3 - (Future Pretreatment Oxidation), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels; Media Filtration; Chlorine
Alternative Train No. 4 - (Future Pretreatment Oxidation), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Media Filtration; GAC Vessels, Chlorine
Alternative Train No. 5 - Pretreatment Ozonation, Lime Softening Clarification; Bio GAC Media Filtration, Chlorine
Alternative Train No. 6 - (Pretreatment Oxidation, Coagulation, Sedimentation) Greensand Media Filtration; NF/RO Softening, Chlorine
Alternative Train No. 7 - Pretreatment Oxidation, Coagulation, Sedimentation, Micro/Ultra Filtration; NF/RO Softening, Chlorine

The below table provides a summary of the estimated OM&R Costs of the options considered. Complete breakdown of the estimates are include in Appendix F. These costs will be re-evaluated upon the completion of all planned bench and pilot testing. Based on the design and planning level of this report (Feasibility) it is estimated that these costs are accurate to approximately 15-20% +/-.

Summary of Crow MR&I WTP O&M Costs (Opinion of Probable Project Costs)				
Figure 3.5.3.3	Cost per Thousand Gallons Produced-OM&R			
Treatment Train Alternative Descriptions	*2.0 MGD*	*2.6 MGD*	*3.5 MGD*	*4.5 MGD*
Alternative Train No. 1 - Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels, Micro/Ultra Filtration; Chlorine	$2.01	$1.84	$1.48	$1.38
Alternative Train No. 2 -– Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation) Micro/Ultra Filtration; GAC Vessels, Chlorine	$2.00	$1.86	$1.53	$1.46
Alternative Train No. 3 - Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels; Media Filtration; Chlorine	$1.90	$1.73	$1.41	$1.31
Alternative Train No. 4 - (Future Pretreatment Oxidation), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Media Filtration; GAC Vessels, Chlorine	$1.90	$1.76	$1.46	$1.38
Alternative Train No. 5 - Pretreatment Ozonation, Lime Softening Clarification; Bio GAC Media Filtration, Chlorine	$1.55	$1.42	$1.12	$1.04
Alternative Train No. 6 - (Pretreatment Oxidation, Coagulation, Sedimentation) Greensand Media Filtration; NF/RO Softening, Chlorine	$1.38	$1.26	$0.95	$0.88
Alternative Train No. 7 - Pretreatment Oxidation, Coagulation, Sedimentation, Micro/Ultra Filtration; NF/RO Softening, Chlorine	$1.44	$1.32	$1.00	$0.93

Figure 3.5.3.3 - Alternatives OM&R Cost Estimate Table


Summary of Crow MR&I WTP Capital Costs (Opinion of Probable Project Costs) - FIgure 3.5.3.4
$2.00
$1.75
$1.50
$1.25
$1.00
$0.75
$0.50
$0.25
$0.00
2.0 MGD
2.6 MGD
3.5 MGD
4.5 MGD
Alternative Train No. 1 - Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels, Micro/Ultra Filtration; Chlorine
Alternative Train No. 2 -– Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation) Micro/Ultra Filtration; GAC Vessels, Chlorine
Alternative Train No. 3 - Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels; Media Filtration; Chlorine
Alternative Train No. 4 - (Future Pretreatment Oxidation), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Media Filtration; GAC Vessels, Chlorine
Alternative Train No. 5 - Pretreatment Ozonation, Lime Softening Clarification; Bio GAC Media Filtration, Chlorine
Alternative Train No. 6 - (Pretreatment Oxidation, Coagulation, Sedimentation) Greensand Media Filtration; NF/RO Softening, Chlorine
Alternative Train No. 7 - Pretreatment Oxidation, Coagulation, Sedimentation, Micro/Ultra Filtration; NF/RO Softening, Chlorine

3.6 Treatment Process Train Alternative Evaluation

Figure 3.6 Treatment Process Train Alternative Evaluation

Alternative	Capital Cost**	OM&R Cost ($/1000 at 4.5 MGD)**	TOC –DBP Precursor Reduction Goal	Operator Level*
1	**$24,633,000**	**$1.38**	**No**	**Level 4 (90-100 points)**
2	**$19,975,000**	**$1.46**	**Yes**	**Level 4 (100-110 points)**
3	**$24,167,250**	**$1.31**	**No**	**Level 4 (110-120 points)**
4	**$19,551,150**	**$1.38**	**Yes**	**Level 4 (100-110 points)**
5	**$19,033,650**	**$1.04**	**No**	**Level 4 (100-110 points)**
6	**$20,824,200**	**$0.88**	**Yes**	**Level 4 (80-90 points)**
7	**$21,279,600**	**$0.93**	**Yes**	**Level 4 (75-85 points)**

*Operator Level Worksheets are provided in Appendix G.

*Costs will be re-evaluated upon the completion of all planned bench and pilot testing.

Evaluation Notes:

Alternative Train No. 1 - Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels, Micro/Ultra Filtration; Chlorine

- Highest Capital Cost due to MIEX system
- High O&M Cost due to High Lime Dosage rates, Lime Disposal, MIEX operating costs
- Will not meet TOC reduction goal, likely issues with DBP in distribution system

Alternative Train No. 2 – Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation) Micro/Ultra Filtration; GAC Vessels, Chlorine

- Lower Capital Costs
- Highest O&M Costs due to GAC replacement, reactivation
- Will meet TOC reduction goal; Lime softening and GAC combination

Alternative Train No. 3 - Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation), MIEX Pressure Vessels; Media Filtration; Chlorine

- 2nd highest Capital Costs due to MIEX System
- Higher O&M cost due to Lime dosage rates, Lime Disposal and MIEX operating costs

- Will not meet TOC reduction goal-MIEX & Lime not providing enough TOC reduction

Alternative Train No. 4 – Future Pretreatment Oxidation, Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Media Filtration; GAC Vessels, Chlorine

- 2nd lowest Capital Cost
- Higher O&M costs due to GAC Replacement and Reactivation and Lime costs
- Will meet TOC reduction goal; Lime softening and GAC combination

Alternative Train No. 5 – Pretreatment Oxidation (Ozone), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Bio GAC Media Filtration, Chlorine

- Lower Capital Cost
- Lower O&M costs, BAC provides filtration and TOC reduction
- Likely will not meet TOC reduction goal with additional GAC contactors following Bio Filtration step

Alternative Train No. 6 - (Pretreatment Oxidation, Coagulation, Sedimentation) Greensand Media Filtration; NF/RO Softening, Chlorine

- Middle capital Cost
- Lowest O&M Cost, Greensand performs dual filtration and FE-MN removal
- Will meet TOC Reduction goal, NF/RO process

Alternative Train No. 7 - Pretreatment Oxidation, Coagulation, Sedimentation, Micro/Ultra Filtration; NF/RO Softening, Chlorine

- Middle capital Cost
- 2nd lowest O&M Cost
- Will meet TOC Reduction goal, RO process

In the initial CTWRD MR&I Water Treatment decision analysis document (February 2015) the Crow Tribe identified the following items as important items to analyze in order to determine the Water Treatment process options:

- OM&R and Capital Costs
- Operation and Maintenance
    - Labor Intensity
    - Technical Difficulty
    - Operation, Maintenance, and Replacement (OM&R) costs
- High quality water-The Tribe wants to produce high quality water for Tribal members and to market to commercial/industrial users for potential revenue. High quality water is defined as follows by the Crow Tribe: Primary Drinking Water Standards, Softening Water, Secondary Drinking Water Standards, DBP compliance

These items along with those identified within this report will revaluated after all piloting and bench scale testing is complete.

4 Bench Scales Testing

4.1 Bench Scale Testing Completed and Results

The following table contains a summary of the Bench Scale testing that has been completed or is planned to be completed. Results of the completed testing can be found in Appendix D of the report.

Figure 4.1 Bench Scale Testing Information

Bench Scale Testing						
Treatment Process	Bench Scale Testing Applicable	Testing Performed	Testing Dates	Testing Parameters	Testing Parties	Result Notes
Media Filtration	NA, Media Filtration Performance Data Available from Hardin, MT WTP-similar source water	NA	NA	NA	NA	Hardin WTP information See Report References
MF/UF	Yes, Accepted range removal percentages received from manufacturers	NA	NA	NA	NA	Accepted removal ranges shown in Mass Balance Diagram
BAC Filtration	NA	NA	NA	NA	NA	BAC typically is a longer bench/pilot testing requirement; typically piloted in applicable
NF/RO	Yes, Accepted range or removal percentages received from manufacturers	NA	NA	NA	NA	Accepted removal ranges shown in Mass Balance Diagram , ROSA Analysis provided in Appendix D
Lime Softening	Yes	Bench Scale Jar Testing	April-May 2015	TOC/DOC Reduction, UV 254, SUVA, Hardness Removal, Iron & Manganese Reduction	Water Technology Group, Denver CO (Merrick Industries)	Lime Dosage rate-200-300 mg/L TOC Reduction or 0-30%
Ion Exchange-MIEX®	Yes	Jar Testing	March 2015	DOC Removal, UVA Removal, Color Removal, Hardness Removal, Iron Removal, Manganese Removal	IXOM Watercare,Inc.	DOC Reduction=35% UVA Reduction=61% Hardness Reduction=53% Iron Reduction-Potassium Permanganate=95% Iron Reduction-MIEX=83%
GAC Post-Treatment	Yes	Bench Scale Column Testing	April-May 2015	DOC/TOC Removal; GAC breakthrough/ media lift	EPS Labs	EPS labs performing RSSCT Testing, initiated 6-5-15, results to be included in Final Pilot WTP Report
Pretreatment-Coag/Floc/Sed Clarifier or Plate Settlers	Yes	Bench Scale Jar Testing	April 2015	TOC/DOC, UV254, SUVA ORP, Iron, MN, pH, Turbidity	CTWRD & BW	Coagulant addition provided no visible improvement to the oxidation bench scale testing results
Ozone	Yes	Ozone Demand Study	February 2015	Iron, MN, Color, DOC/TOC, Bromide/Bromate, ORP	Pinnacle Ozone Solutions, LLC (Guardian Lab)	Optimum FE removal Dosage=0.79-1.25 O3 mg/L Iron Reduction=97%+ Manganese Reduction=90% TOC/DOC Reduction=0-5% Bromate Formation <1 ug/L

Oxidation-FE/MN Removal	Yes	Bench Scale Jar Testing	April 2015	TOC/DOC, ORP, Iron, MN, pH, Turbidity	CTWRD & BW	Chlorine-little to no positive affect Permanganate Iron Reduction=92%+ Manganese Reduction=80-90%
Greensand Filtration	Yes	Bench Scale Column Testing	Not yet determined	UV absorbance, TOC/DOC, Iron & Manganese	NA	Decision was made to not bench scale test, green sand will remove iron and manganese and provide filtration similar to what Hardin experiences
DBP Formation-SDS Testing	Yes	Lab Testing	Not yet determined	DBP; TTHM, HAA5	CTWRD & BW	Testing Initiated 5-29-15, results to be included in Final Pilot WTP Report

4.2 Bench Scale Testing Planned

As noted above in section 4.1, Bench scale testing is currently ongoing for GAC-RSSCT testing and SDS testing. The test result from these tests will be included within the Final Pilot WTP Report. Greensand media column testing, BAC media column testing, will not be bench scale testing. Preliminary Simulated Distribution Testing (SDS) will be performed prior to and during piloting in order to determine necessary DBP levels and TOC reduction goal.

4.3 Water Age-DBP/SDS Testing

Based on preliminary system modeling the water age of the most remote area of the Crow MR&I system is approximately 40-50 days. The longest residence times occur in the northern areas of the Pryor Extension as well as the Cloud Peak extension. The addition of the primary disinfectant when leaving the distribution plant may cause the potential for formation of disinfection by-products. In order to accurately determine the necessary TOC/DOC levels associated with the DBP formation for this time period a Simulated Distribution Simulation (SDS) is needed. Regulated disinfection by-products and their maximum contaminant levels are listed in Appendix B. The best way to reduce the DBP formation in the planned large distribution system will be to remove the precursors before the treated water leaves the WTP.

A DBP formation potential analysis is used to evaluate the greatest amount of DBP formation that is possible in a given source water. The longer the distribution time, the closer this DBP Formation Potential value is to the SDS value. In all cases SDS is the preferred test as it represents similar conditions to what is expected in the distribution system. In order to capture the DBP formation of the treated water and simulate the expected water age in the distribution system, a SDS test is performed. To execute this testing, samples will be collected from the filtered raw water and blended with ultrapure water (TOC≈0) to create varying levels of TOC in the samples. The SDS testing will target TOC/DOC level of 0.50, 1.0, and 1.5. After collecting the samples a water stability analysis and calculation will be conducted to determine the Langelier Stability Index. This index will provide a determination of the amount of buffer (sodium hydroxide or borate) dosing necessary to stabilize the pH at approximately 8. These samples will be chlorinated, and then held in a container to simulate free chlorine contact time. The samples will be dosed with free chlorine at a dosage to yield approximately 2.0 mg/l free chlorine residual at the end of the contact period. Sample pH, temperature, total chlorine, and free chlorine residual will be checked and recorded. Samples will be capped with Teflon covers in clean amber glass bottles or

clear glass bottles covered in aluminum foil and stored for 15, 30, 45 (and potentially longer if needed) days at room temperature (or refrigerator or cooler), in the dark (exact sample times will be dependent on the testing lab schedule). Sample pH, temperature, total chlorine, and free chlorine residual will be rechecked and recorded at the end of the storage period. Samples will then be withdrawn and placed in special sample vials (from the certified testing laboratory) containing sufficient sodium thiosulfate to dechlorinate the sample. Blank samples (distilled deionized water) will also be prepared and subjected to all the same chemical additions. Total trihalomethanes (TTHM) and total haloacetic acids (HAA5) will be determined for each sample by an independent laboratory. A similar test will be conducted, except after the free chlorine contact time, ammonium sulfate will be added (at a 1 to 4 NH3-N to Cl2 weight ratio) to convert from a free chlorine residual to a combined chlorine residual. The remainder of the test will remain as indicated previously except total chlorine will be analyzed in lieu of free chlorine. A complete SDS testing protocol with conditions of testing are included in Appendix H.

SDS results will be provided in within the Final Pilot WTP Design Report. Data will be presented with both raw data and in graphical form. Graph will provide total THMs and HAA5s in ug/L and will be plotted with water age. Regulatory limits for THMs (80 ug/L) and HAA5s (60 ug/L) will also be plotted in order to show the project data versus regulation limits. The key data that will be confirmed through this process is the TOC/DOC goal of 1.25 mg/L.

5 Pilot Scale Testing

5.1 Pilot Scale Testing Alternatives

Based on the information presented in the previous section the following alternatives are being considered for further pilot testing:

Alternative Train No. 1 - Will not be piloted due to high capital costs, high OM&R costs, and inability to reduce DBP precursors.

- Option will not be piloted
- High capital costs & OM&R cost will be revaluated after all piloting and bench scale testing is complete
- The process will need to include additional TOC/DOC removal

Alternative Train No. 2 – Will not be piloted due to having the highest OM&R costs of the options evaluated

- Option will not be piloted
- High OM&R cost will be revaluated after all piloting and bench scale testing is complete
- Lime and GAC usage rate will be evaluated further

Alternative Train No. 3 - Will not be piloted due to high capital costs, high OM&R costs, and inability to reduce DBP precursors.

- Option will not be piloted
- High capital costs and OM&R cost will be revaluated after all piloting and bench scale testing is complete
- The process will need to include additional DOC removal

Alternative Train No. 4 – Will not be piloted due to having high OM&R costs

- Option will not be piloted
- High OM&R costs will be revaluated after all piloting and bench scale testing is complete
- Lime and GAC usage rate will be evaluated further

Alternative Train No. 5 – Pretreatment Oxidation (Ozone), Lime Softening Clarification (including Flocculation, Coagulation, Sedimentation); Bio GAC Media Filtration, Chlorine

- Option will be further evaluated during piloting process
- GAC Contactors will be necessary following Bio-GAC Filtration to lower DOC levels to meet goals
- Since it is likely the process will need to include additional DOC removal the option will be re-evaluated following GAC RSSCT and SDS testing to determine if option is cost effective
- Lime Softening Clarification will not be piloted due to size constraints and information collected thru bench scale testing

Alternative Train No. 6 - (Pretreatment Oxidation, Coagulation, Sedimentation) Greensand Media Filtration; NF/RO Softening, Chlorine

- Option will be further evaluated during piloting process
- Greensand filtration will not be piloted due accepted process values available

Alternative Train No. 7 - Pretreatment Oxidation, Coagulation, Sedimentation, Micro/Ultra Filtration; NF/RO Softening, Chlorine

- Option will be further evaluated during piloting process

Pilot Testing to Include:

- Oxidation- Permanganate & Ozone
- Pretreatment Coag-Floc-Sedimentation (Plate Settler)
- Filtration-MF/UF, Bio GAC Media Filter
- Softening-NF/RO

**Sufficient Information Available from Bench Scale testing for Greensand Media Filtration and Lime Softening Clarification

5.2 Pilot Scale Testing Plan

Pilot testing of the recommended design alternatives will be conducted. Pilot testing will further determine the TOC/DOC, iron, manganese reduction (along with other treatment goals identified) can be sustained for longer period of times. Piloting will collect a large quantity of data, examples of this information include:

- Demonstration that the equipment will produce treated water that will meet all applicable federal and state standards.

- Further analyze softening process
- Provide physical design parameters (flux, recovery, backwash frequency, cleaning frequency, etc.) for basis of the final full-scale design.
- Demonstrate the ability of the system to provide verification of membrane integrity
- Determine the ability of the systems to remove total organic carbon (TOC) and other contaminants of concern such as aluminum, iron, and manganese
- Determine the impact of chemical additions (permanganate, ozone, polymer, coagulant) on the membrane operation.
- Determine oxidants such as ozone and permanganate are effectiveness in conjunction with filtration, settling, and other equipment
- Account for unforeseen conditions that may have otherwise gone undetected.
- Familiarize operators with the process equipment
- Determine biological activity formed and effect on TOC, metals, fouling, cleaning, and other parameters
- Determine the amount of reject water, system recovery, process efficiency, particulate/organism removal efficiencies, cold and warm water flux, fouling potential, operating and transmembrane pressure, and other design and monitoring considerations.

Pilot testing will provide accurate results so that factors for each process can be adjusted and optimized to determine ideal operating conditions. The data collected by the pilot study will be utilized by the Crow Tribe to determine the effectiveness of the final alternatives to meet water treatment goals outlined in previous section of this report. The data will also aid in the final design of the technology by determining the cost-effective implication and design criteria.

6 Design Schedule

6.1 Crow MR&I Water Treatment Plant Design Steps

Design process diagram and schedule are shown on the following figures.

Schedule Items of Note:

- Operation of the Pilot WTP is being proposed to operate for a length of 3 months. Variations in raw water quality shown in Appendix A have shown the following:
    - Temperature fluctuation is not highly variable and only change from 5-20˚ C thought the year
    - TOC-DOC peak stays consistent between Mid/Late June through September
    - Turbidity levels are stable throughout the year with the exception of significant rain and snow events
    - Turbidity events will be stabilized due to the use of River Bank Filtration
    - Iron, Manganese, Hardness, Alkalinity, ORP have shown to be consistent and have little seasonally variation

Figure 6.1 Preliminary Design Schedule for the MR&I WTP

Design Process Schedule for the Crow MR&I Water Treatment Plant

			June				July				August				September				October				November				December				January			
Item #	Task	Description	1-Jun	8-Jun	15-Jun	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug	17-Aug	24-Aug	31-Aug	7-Sep	14-Sep	21-Sep	28-Sep	5-Oct	12-Oct	19-Oct	26-Oct	2-Nov	9-Nov	16-Nov	23-Nov	30-Nov	7-Dec	14-Dec	21-Dec	28-Dec	4-Jan	11-Jan	18-Jan	25-Jan
1	Alternative Design Report	Analysis of Treatment Alternatives																																		
2	Bench Scale & SDS Testing	Perform Bench and other lab testing identified in Task #1																																		
3	Pilot Test Report, Plans, & Specifications	Prepare pilot planning, construction, and operating documents																																		
4	Pilot Water Treatment Plant Construction	Construction facility described in Pilot plant Test Plans and Specifications																																		
5	Pilot Plant Testing	Operate pilot water treatment plant and collect data																																		
6	Final Alternative Analysis and Bench & Pilot Testing Results Report	Prepare and finalize Bench and Pilot testing data in report form along with updated analysis performed in Intial Alternative Report																																		
7	WTP Process Decision Memo	Prepare and Transmit Memo of Process Decsion based on Recommendation of report noted in previous task																																		
8	Preliminary Design Report	Perform preliminary design related to prcoess, floor plan, site layout, etc.																																		
9	35% Design (2016)	Drawings, Costs, Specifications, and BOR & EPA Review at 35%l Design																																		
10	Value Engineering Study (2016)	Conduct value engineering study of 35% design																																		
11	95% Design (2016)	Drawings, Costs, Specifications, and BOR & EPA Review at 95% Design																																		
12	100%/Final Design (2016)	Drawings, Costs, Specifications, and BOR & EPA Review at 100%/Final Design																																		
13	Crow Tribe Bidding Process (2016)	Advertise, Bid, and Award Water Treatment Plant																																		
14	Facility Construction (2016)	Construction and Startup of Water Treatment Plant																																		

Design Process for Crow MR&I Water Treatment Plant

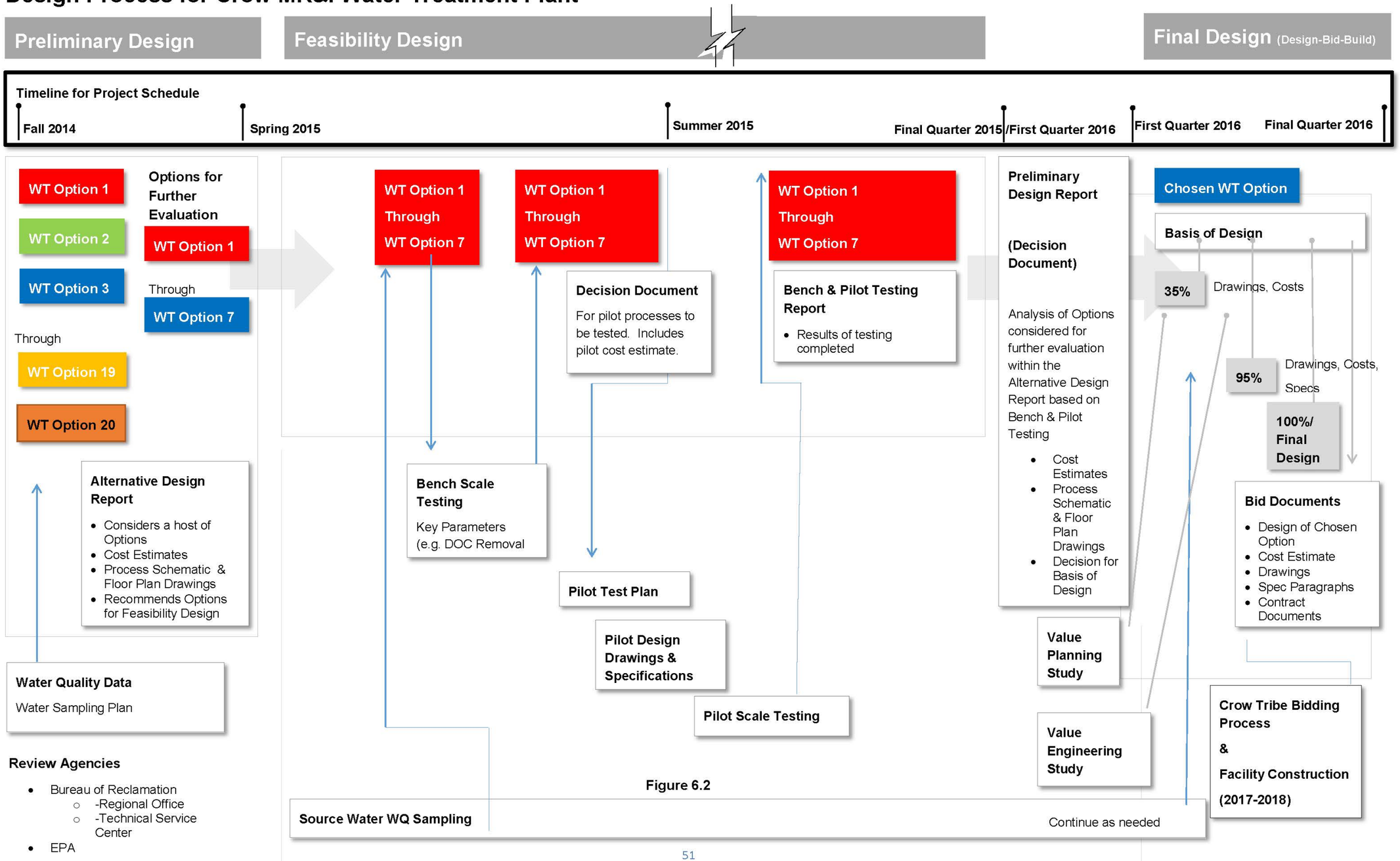


Figure 6.2

7 References

[1]"Crow MR&I Master Plan" –Crow Tribe Water Resource Department, and Bartlett & West, September 2014

[2] "Treatment of Concentrate" "-Desalination and Water Purification Research and Development Program Report No. 155", United State Department of the Interior, Bureau of Reclamation, 2009

[3] "City of Hardin Preliminary Engineering Report-Water System", City of Hardin and Great West Engineering, April 2010

-Hardin Treatment Information and Water Quality

[4] (EPA, 2015)"Drinking Water Treatability Database", http://iaspub.epa.gov/tdb/pages/treatment/findTreatment.do , US Environmental Protection Agency, June 2015

8 Appendices

Appendix C. Decommissioning and Reclamation Plan

Crow Tribe Water Resources

CROW MR&I SYSTEM
PILOT WATER TREATMENT PLANT PROJECT
Decommissioning and Reclamation Plan
MARCH 2015

CROW TRIBE

BARTLETT & WEST

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1.0 Waste Material Handling & Disposal Facility Decommissioning

Waste material generated during the construction or operation of the pilot plant or aquifer test will be handled according to all applicable hazardous materials rules and regulations. Pilot test equipment operation such as ozone generation that produces potentially harmful substances, will be operated in a manner compliant with all applicable health and safety codes. Concentrate solid waste material generated during water treatment will be excavated from the evaporation pond and hauled to the nearest appropriate landfill. The St. Xavier Canister site will not be appropriate for landfill. The Reno Creek solid waste disposal site, Crow Agency Open Dump solid waste disposal site, or Lodge Grass Open Dump solid waste disposal site will be evaluated for appropriateness for placement of membrane backwash sludge and sediment sludge.

2.0 Facility Decommissioning

The supply and discharge pipelines, pilot plant building, and equipment would be removed from the ground surface. Following removal the materials will be stored in a secure area and protected from damage. The treatment skids (ozone, plate settler, ultrafiltration, and reverse osmosis) will be decommissioned in accordance with manufacture standards. Following decommissioning the skids would be shipped back to the respective manufacturers. The pipelines and structure would be salvaged by the Tribe.

3.0 Ensuring Subsurface Integrity

Subsurface work on the project includes a groundwater intake well of approximately 30’ depth, 7-10 observation wells, and 50 feet of pipeline trench of approximately 2’ depth and 2’ width at the Mission Loop Road Crossing. At the conclusion of aquifer testing and pilot plant operation, the groundwater intake wells and the observation wells will remain in place for potential later use during the ultimate intake construction. The groundwater well internal components will be removed and the casing will be capped until further need develops. The electrical service will be discontinued, but the service panels and lines will remain in place for future use unless the site is abandoned as an alternative for the full-scale plant intake location.

If the site is determined to be unfeasible for the full-scale plant intake, the electrical service will be completely removed and any buried lines will be abandoned. The groundwater well and observation wells will remain in place, but will be fully decommissioned by capping and sealing the wells below the surface and backfilling over the top of the wells.

4.0 Surface Reconstruction and Stabilization

Disturbed landscape will be returned to approximate original contours, with added geomorphic stabilization in areas weakened by construction and project activities. The area disturbed for construction of the settlement pond and pilot plant site will be backfilled and re-contoured to near pre-construction contours. Disturbed surfaces will be returned to original purpose. Erosion and sediment control best management practices (BMPs) will be implemented to protect the reclaimed area and

adjacent features from sediment wash out, livestock, wind, or other significant factors such as human use during and after construction. BMPs and surface reconstruction/seeding will be established in the project Stormwater Pollution Prevention Plan (SWPPP).

5.0 Re-Establishing Surface Hydrology

Damaged or disturbed drainages, impoundments, stream banks or channels will be repaired or restored to match original or adjacent drainage patterns, profiles and dimensions. The characteristics of the original surface hydrology, in the potentially disturbed area, will be captured in applicable documentation such as photos, topographical survey or soil survey for guidance and comparison during the re-establishment/reclamation period. Other components impacting surface hydrology such as vegetation will be considered in the soil preparation and revegetation efforts.

6.0 Soil Management and Handling

Soils in the project area have been delineated using the Natural Resource and Conservation Service (NRCS) web soil survey tool. Descriptions of the soil resources can be found in the project Environmental Assessment. Top soils will be segregated from excavated sub soils and fill materials and will be protected from erosion, degradation and contamination. Upon completion of the project, the top soil will be reapplied to surface of the recontoured area.

7.0 Site Preparation

Preparation of the site for revegetation will begin with proper pre-construction activities. Noxious weeds and noxious weed infested topsoil will be removed prior to seedbed preparation and disposed of in an appropriate landfill. Seedbed preparation will include removal of stiff clods, lumps, roots, litter, stones, and other foreign material greater than 6 inches from the surface, and filling of rills, gullies and depressions. Areas where topsoil was disturbed by excavation will be scarified or harrowed and raked prior to sowing seed or placement of fertilizer.

8.0 Revegetation

The revegetation effort, including seeding methods and seed mixes, will meet the requirements of the construction specifications which will be developed in cooperation with the BIA Environmental Resource Department and the local NRCS. Revegetation will occur in conjunction with site preparation and will generally include seeding and mulching. Seeding is generally done by broadcast, drill, or hydroseed methods. Seed mixes will include native species and may include a cover crop, unless the BIA or landowner desires otherwise. Seeding in previously cultivated/agricultural fields will be based on BIA approval.

9.0 Restoring Visual Resources

Impacts to visual resources will be minimized during establishment of the work limits within the project area before construction commences. Disturbed areas such as the backfilled evaporation pond will be dressed, seeded, mulched and returned to the original state as quickly as possible at the conclusion of construction. Temporary pipeline will be placed in such a way that minimizes eyesore during the project and will be removed at the conclusion of the project. Temporary project facilities such as electrical services will remain onsite until the project location is deemed unsuitable for the full-scale plant intake and or pipeline. If the site is deemed unsuitable, electrical service panels, boxes, wells heads, and other visible project facilities and materials will be removed from the site.

10.0 Weed and Pest Management

Noxious weeds and noxious weed infested topsoil will be removed prior to seedbed preparation and disposed of in an appropriate landfill. Until substantial completion for the SWPPP is met, the site will be monitored for noxious weeds.

11.0 Monitoring

Monitoring and reporting procedures will be developed in the project SWPPP. Land reclamation and revegetation goals will be a significant consideration in the development of the SWPPP.

12.0 References

BLM (Bureau of Land Management). 2011, October 18. Reclamation Policy Plan Requirements Retrieved December 3, 2014, from http://www.blm.gov/wy/st/en/programs/reclamation/plans.html

Appendix D. Public Notice Documentation

<Placeholder for future documentation within Final EA.>