ORANGE COUNTY DISTRIBUTION SYSTEM

HYDRAULIC MODEL PHASE 1 – MODEL INVESTIGATION

B&V PROJECT NO. 402183
B&V FILE NO. 40.0000

PREPARED FOR

Municipal Water District of Orange County (MWDOC)

14 FEBRUARY 2020

Prepared by:	Meghan Merlihan Scott Joplin
Reviewed By:	Kevin Laptos, P.E. Matt Thomas, P.E.
Submitted by:	Matt Thomas, P.E., Project Manager

Table of Contents

List of Tables

List of Figures

1.0 Introduction

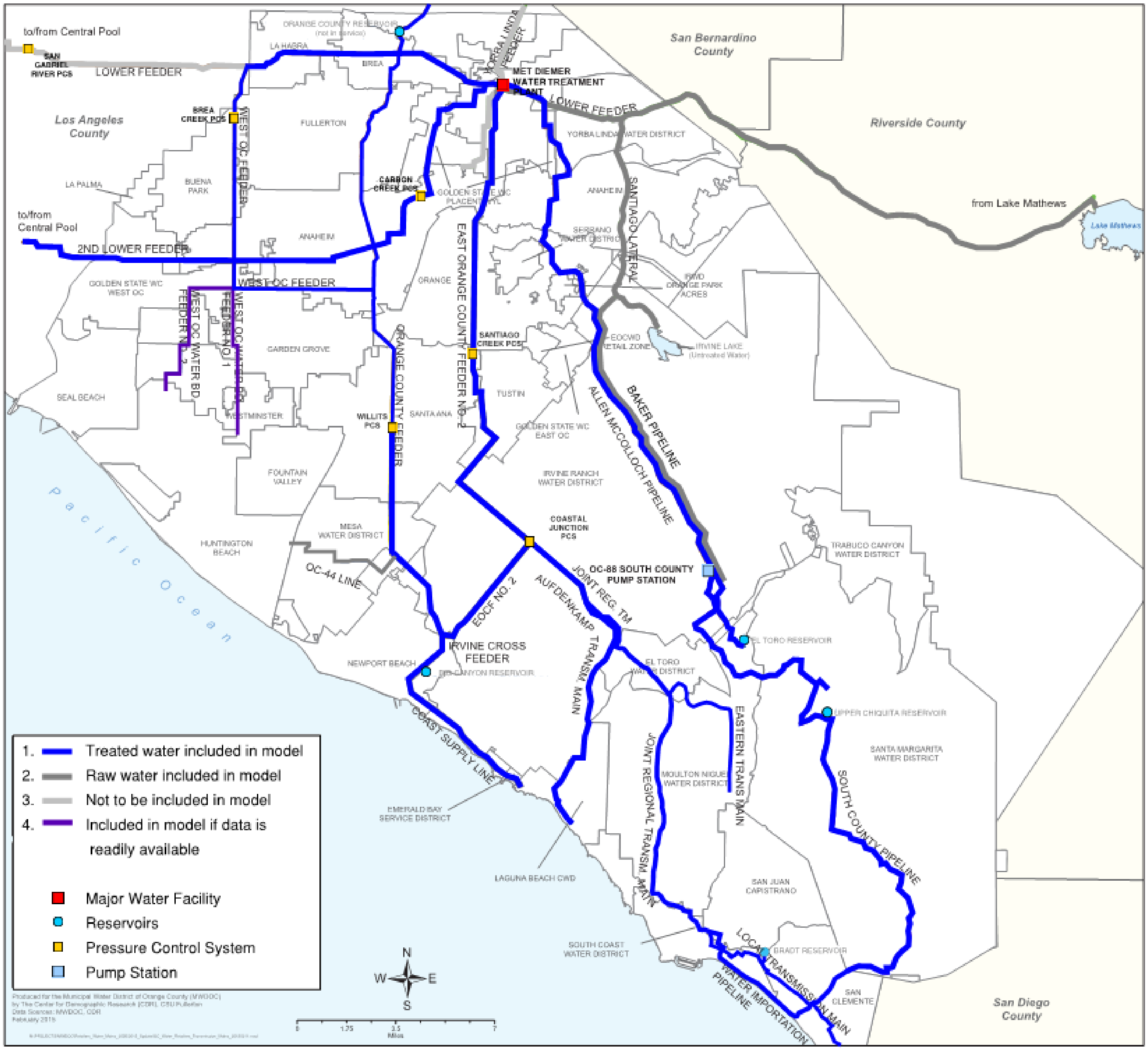
Black & Veatch is currently supporting the Municipal Water District of Orange County (MWDOC) in the development of a hydraulic and water quality model of the Orange County regional distribution system. The model, referred to in this report as the Hydraulic Model, will be a tool to help evaluate the feasibility and impacts of integrating new local water supply projects into the existing system, as well as to evaluate a variety of operational and emergency scenarios to support on-going system operational planning. The Hydraulic Model tool will also be available to support other needed system hydraulic and water quality investigations.

1.1 OVERVIEW

The Phase 1 Evaluation of Hydraulic Model development is comprised of:

- An evaluation of various software alternatives and recommendation of a preferred software application for the Hydraulic Model.
- A recommended Work Plan for building and calibrating the model.

Figure 1-1 below shows an overview of the proposed model area. This Phase 1 Evaluation Report summarizes the background information review, needs assessment, software selection evaluation, and stakeholder engagement used to inform software selection and work plan development.



Produced for the Municipal Water District of Orange County (MWDOC)
by The Center for Demographic Research (CDR), CSU Fullerton
Data Sources: MWDOC, CDR
February 2015

Figure 1-1 Overview Map

1.2 EVALUATION PROCESS

To determine the appropriate Hydraulic Model software application for Orange County, and to help define the work plan for implementation of the Hydraulic Model, MWDOC retained Black & Veatch to assist in a multi-step evaluation process, summarized in this report. The evaluation process included:

- **White Papers.** Black & Veatch and Hazen & Sawyer were previously retained to identify key technical issues associated with the integration of new water supplies into the Orange County regional distribution system and to local agency water systems. This work included identification of subsequent technical analyses needed to address local supply integration issues. Those efforts resulted in a number of recommendations, which are summarized in two White Papers (Appendix 1). The White Papers identify a variety of uses for a system hydraulic model that are incorporated into this Phase 1 Evaluation report.
- **Data Collection and Review of Background Information.** Black & Veatch collaborated with MWDOC and its Member Agencies to obtain information that would be relevant to identifying potential hydraulic modeling needs and data that would be useful in model development.
- **Stakeholder Engagement.** MWDOC engaged with its Member Agency stakeholders to obtain input about the needs for a hydraulic model. This effort included:
    - **Questionnaire -** MWDOC sent questionnaires to the Member Agencies requesting information about their potential needs for a hydraulic model, as well as for information and data that could support development of such a model.
    - **Workshops** – MWDOC conducted several workshops with Metropolitan Water District of Southern California (Metropolitan); and both together and separately, with MWDOC's Member Agencies to obtain feedback from stakeholders. The discussions focused on the issues associated with new water supply integration, the needs and expectations for technical analyses and modeling, and reviews of the recommendations of the White Papers.
- **Software Selection Evaluation.** Black & Veatch conducted in depth analysis to compare various software platforms that could be used to develop the Hydraulic Model. This analysis is described herein.
- **Work Plan.** With the support of MWDOC, Black & Veatch developed a work plan to build and calibrate the Hydraulic Model using the selected software platform.

2.0 Data Collection and Review

To support the Phase 1 Evaluation effort, Black & Veatch and MWDOC together contacted Metropolitan and MWDOC's Member Agencies to obtain available information and data that could be used to facilitate Hydraulic Model development and support technical analyses for on-going operational scenarios and new supply integration studies.

Black & Veatch developed a System Information Database (SID) to document the available data and information available to support development of the Hydraulic Model. The SID is presented in Appendix 1 of the **Data Review Technical Memorandum** prepared for MWDOC in 2019. The Data Review Technical Memorandum is presented in Appendix 2 of this Phase 1 Evaluation report. The SID details which data has been already provided to Black & Veatch and which other data will be needed from MWDOC, Metropolitan, and MWDOC's Member Agencies to support model preparation and subsequent analytical studies.

The data is organized into the following categories:

- Demand and Supply Data,
- Water Quality Data,
- Hydraulic Model Data,
- Geographic Information System (GIS) Data,
- Operational Data, and
- Miscellaneous Data.

The data includes the source, format and date that information was received. Black & Veatch will utilize the existing SID to define, prioritize, and request any additional system data/information that will be needed to build and calibrate the Hydraulic Model.

3.0 Stakeholder Outreach and Input

As noted earlier in this report, MWDOC conducted outreach and obtained input from key stakeholders, including Metropolitan, Water Quality consultants, and MWDOC's Member Agencies. The workshops focused on the potential needs for a model, technical analyses that would be required to successfully integrate new water supplies into the Orange County distribution system, and to ascertain data availability to facilitate these efforts.

The input received from informal discussions, workshops, and questionnaires is reflected in this Phase 1 Evaluation report within the evaluation criteria described in the software evaluation and is reflected in the work plan. It is also reflected in the White Papers (Appendix 1).

3.1 WORKSHOPS

MWDOC's stakeholder outreach efforts included several workshops to discuss issues and obtain feedback with; new water supply integration, alignment of needs, expectations for technical analyses and modeling, and presentation of White Paper results. The workshops were held:

a) August 2018 workshop with Metropolitan, Water Quality Consultants, and MWDOC Member Agencies to discuss new supply integration issues and analysis needs and expectations.
b) February 2019 workshop with select MWDOC Member Agencies at Black & Veatch offices to discuss potential hydraulic modeling approaches.
c) July 2019 workshop with Metropolitan to discuss Metropolitan's comments on the White Papers.
d) November 2019 workshop with South Orange County MWDOC Member Agencies to present White Paper results and obtain feedback about priorities for analyses to support work plan development.
e) February 2020 workshop with all MWDOC Member Agencies to present White Paper results and obtain feedback to support work plan development.

3.2 QUESTIONNAIRES

Questionnaires were developed and sent to MWDOC's Member Agencies for feedback. These questionnaires contained the following questions:

- Does the Member Agency have a current distribution system hydraulic model?
- Which software application was used to build any existing hydraulic models?
- When were any existing models last calibrated?
- What type of analysis is the model used for?
- What are the agencies' future goals, needs, and aspirations related to hydraulic modeling?
- Is GIS being utilized? What platform? For what purpose?

The information provided from the responses to these questionnaires was used to:

a) Identify data that would be available to facilitate development of the overall Orange County regional system Hydraulic Model.
b) Add detail about what capabilities may be desirable in the final software selection.

c) Provide data to support model selection since it may be desirable to select software that is compatible with hydraulic models already in use in Orange County.

4.0 Software Selection Evaluation

4.1 CRITERIA DESCRIPTION

A major component in the success of building a water system model is the selection of a software application that will meet the needs and demands of the intended use for the model. As described earlier, Black & Veatch and MWDOC collaborated with Metropolitan and MWDOC's Member Agencies to define needs and goals for the Hydraulic Model. The technical capabilities criteria outlined in Table 4-1 below were developed as a result of input provided by MWDOC, its Member Agencies, and Metropolitan all resulting from MWDOC's outreach and collaboration efforts. In addition to criteria resulting directly from identified needs, additional criteria unrelated to software capabilities were also considered; including prevalence of the software being used in Orange County, license cost, annual maintenance cost, and technical support provided.

Table 4-1 MWDOC Hydraulic & Water Quality Modeling Report Technical Capability Criteria

MWDOC NEEDS/GOALS	CRITERIA
Simulation of full-pipe pressurized flow conditions which normally exist in most areas of MWDOC's system, as well as, partially-full unpressurized flow conditions in the untreated Santiago Lateral Pipeline.	Software can perform pressurized flow hydraulics and represent open channel flow.
Simulation of steady-state, time-varying (dynamic or extended period simulation (EPS)), and transient (surge) hydraulic conditions.	Software can perform steady-state, time-varying, and transient hydraulics.
Hydraulic simulation of treatment plant supplies, pumping stations, storage facilities, pressure/flow regulating stations, and demand/flow transfer points.	Software can simulate the addition or modification of the listed facilities.
Compatibility with major hydraulic model applications and/or ability to import model data to support model build from other model applications used in Orange County.	Software can import information, and/or GIS data exported from other models, including Mike Urban, and EPANet models.
Capability to expand the model and/or potentially merge with MWDOC member agency models in the future.	The software can merge models of various formats.
Easy to use and reference model results (i.e. tabular, graphical, GIS compatibility)	Software can efficiently display results graphically and export results to GIS, Excel, PowerBI, and other external data analysis and visualization tools.
Model scenario manager capable of storing many hydraulic and/or water quality runs over time.	Software can develop and manage multiple model scenarios.
Capability to track history of edits to model input data and model runs/scenarios.	Software can track physical model data and changes to input parameters from scenario to scenario.
Simulation of system water quality.	Software can perform source trace simulation, water age simulations, and water quality constituent simulations.

4.2 FINAL SOFTWARE COMPARISON AND SELECTION

In order to select the software that would be most suitable for MWDOCs hydraulic model, software market survey results were reviewed. A selection decision support tool was then created in the form of a matrix to generate a score for each of 8 software applications identified for evaluation. This matrix is presented in Appendix 3.

Each software option was given a score of 0 to 3 for each of the 9 criteria listed in Table 4-1. A score of "0" indicated that a software option did not satisfy the criteria, a "1" indicated that a software partially satisfied the criteria, a "2" indicated that a software satisfies the criteria, and a "3" indicated that a software exceeded the requirements of the criteria. Also, a score weighting system was applied to help emphasize the relative importance of each criterion based on the importance of the associated MWDOC need/goal. The weighting factors for the criteria were reviewed by MWDOC before developing the final scoring for the software in the matrix.

After initial scoring, based only on the technical criteria, the four software applications with the highest scores were InfoWorks WS, WaterGEMS, InfoWater, and Synergi water with scores of 73, 72, 70 and 69, respectively. This demonstrated that these four software platforms are similarly capable of meeting the technical requirements of the MWDOC hydraulic model. Since these software platforms are technically similar and would each be suitable for the purposes of the MWDOC hydraulic model, it becomes critical to consider which software is most suitable for MWDOC based on the additional "non-technical" evaluation criteria, including license cost, maintenance cost, prevalence in Orange County and technical support availability. The additional criteria considered are summarized in Table 4-2.

Table 4-2 MWDOC Hydraulic & Water Quality Modeling Report Additional Evaluation Criteria

MWDOC NEEDS/GOALS	CRITERIA
Prevalence and Acceptance in Orange County	Water utilities and agencies using the software for water system modeling locally
License Cost	For comparison purposes, cost of unlimited pipe software license with any additional modules/add-ons that may be needed to meet MWDOC's above Needs/Goals.
Annual Maintenance Cost	Annual cost of software maintenance including version upgrades and technical support supplied by vendor for above software license.
Technical Support	Location of technical support staff. Working hours and days of week of technical support staff.

The above criteria were scored based on:

1. information obtained from the software vendors about license and maintenance costs, and
2. the results of the questionnaire survey sent to MWDOC's Member Agencies about their hydraulic modeling uses and which software they currently utilize.

The combination of the technical criteria scores and the additional evaluation criteria scores provides a more complete evaluation of each software. The combined score for each software alternative is presented on the following page in Table 4-3.

Table 4-3 MWDOC Hydraulic & Water Quality Modeling Report Software Matrix Score Comparison

SOFTWARE	SCORE
EPANet	66
InfoWater	97
InfoWorks ICM	67
InfoWorks WS	87
KY Pipe	75
MIKE Urban	88
Synergi Water	87
WaterGEMS	84

Of the four software (InfoWorks WS, WaterGEMS, InfoWater, and Synergi) which scored high technically, InfoWater was found to be the most prevalent in Orange County and to be the most cost-effective for its technical capabilities. Thus, InfoWater received the highest total score out of the 8 software applications. InfoWater is a water modeling application created by Innovyze that is very prevalent in the industry and has a competitive cost.

Based on the software evaluation and scoring analysis discussed above, the recommended software selection is InfoWater.

5.0 Work Plan

Black & Veatch has developed a conceptual Work Plan for development, calibration, and application of the model. This plan has been divided into the following three phases:

The current Phase 1 of the work plan consists of the analyses performed and described within this report. Descriptions of Phase 2, Phase 3, and Future Phases are described in the following sections. Details for each phase are shown below in Table 5-1.

Table 5-1 MWDOC Hydraulic & Water Quality Modeling Report Work Plan Details

ACTIVITY	DURATION	TIMING	BUDGETARY COST	FUNDING SOURCE
Initial Phases				
Phase 1- Model Investigation	2-3 months	FY 19-20	$75K	MWDOC
Phase 2 - Model Build	2-3 months	FY 19-20	$50K-$75K	MWDOC
Phase 3 – Initial Model Calibration (South County)	3-4 months	FY 20-21	$100K-$150K	MWDOC
Other Future Phases (Timing TBD)				
Build and Calibrate Raw Water System Model	4-6 months	TBD	$50K-$150K	TBD
Calibrate Remainder of Model (North County)	3-4 months	TBD	$100K-$150K	MWDOC
New Supply Integration Studies (White Paper/Study Plan)	Varies	Varies	Varies	Project Proponents or Shared Services

5.1 PHASE 2: MODEL BUILD

Model Build will begin by establishing a pipe network for physical model development with data that has been requested and collected as described in detail in Section 2. Necessary attributes that are to be included in the data include: pipe diameter, pipe material, pipe installation year, node elevation data, and node subtype data. The extent of the transmission system and data sources to be used to create the Hydraulic Model are shown on the following page in Figure 5-1.

Once the pipe network is established in the model, system facilities including Metropolitan's Water Treatment Plants and other pump stations, storage reservoirs, and pressure control structures (PCS) will be added as is also shown in Figure 5-1.Data for these facilities will consist of:

- Number of pumps and pump control valve size and type
- Pump manufacturer performance curves and/or recent field-tested pump curves
- Current pump operating controls and settings
- Storage facility volume, dimensions, and elevations
- Number of PCS valves, valve size and type, and operating controls and pressure/flow setpoints
- Wholesale water meter locations and sizes for locations within MWDOC's system including Member Agency service connection points and pumping stations

The next step in the model build process following physical model development will be to incorporate water demands into the Hydraulic Model. Southern California has historically had varying demand patterns due a statewide drought followed by recent wet years. It is imperative that flow and demand data is provided by MWDOC and Metropolitan to accurately depict these varying conditions. Furthermore, future demand projections for those same conditions (high and low demands) at all service connections within the Hydraulic Model will be needed. This data will be used to develop typical diurnal demand patterns for each of the service connections. This approach for developing and assigning system demands will allow MWDOC to perform "dynamic" extended period simulations (EPS) with their hydraulic model.

Figure 5-1 Extent of Proposed Model

Phase 2 of the Work Plan will provide the following:

1. GIS-based dynamic EPS hydraulic model
2. Simulation of basic system hydraulics and operations
3. Mass balance/delivery quantities simulations
4. Conceptual simulation of pressures and water age/water quality evaluations, however the model will require calibration to provide reliability

5.2 PHASE 3: INITIAL MODEL CALIBRATION

Phase 3 of the work plan is to perform an initial calibration of the Hydraulic Model. The initial focus will be to accommodate near-term needs of the model in the south Orange County area funded by project proponents. Efforts included in this phase will consist of utilizing available pressure and flow data from Metropolitan, MWDOC, and Member Agencies. This phase will allow the Hydraulic Model to provide for the simulation of varying pressures, water age/quality evaluations, and water source blending. The water age and source blending model results, when exported to an external water quality model, will also support simulation/prediction of disinfection residual decay and/or other kinetic water quality parameters.

The plan to create a reliable model that can provide the simulations listed above will begin with an initial calibration to ensure the model is accurate and reasonable for the purposes of intentional use. The area of focus for the initial calibration is shown in Figure 5-2. The model will also be capable of extending its calibration efforts to encompass future modeling needs.

The calibration process compares model output results to actual system operational data and adjusts model input data, if/as needed, to produce an acceptable match. The consultant will need to review available system operational records to develop a calibration plan for the Hydraulic Model that will define locations within the system where operational parameters will be compared. In the process of developing a calibration plan, it is possible that "gaps" in the available system operational data will be identified. If the data gaps are significant enough to impact the model calibration accuracy, the consultant will recommend locations in the system where pressure and/or flow monitors should be temporarily installed to complete the data set. The calibration plan development will also consist of reviewing historical system flows and demands as previously described to identify an appropriate period of time for model calibration. The time period selected will depend on when system demands were higher to obtain operation data when the system was "stressed" but will avoid time periods when anything unusual may have been occurring, such as a major main break or facility outage.

Figure 5-2 Area to be Calibrated

After the plan is developed and calibration has begun, the consultant will conduct a continuous simulation for the selected calibration period to verify the model's ability to simulate a variety of demand and operating conditions. This simulation will include comparisons of the model results to SCADA/operational data from MWDOC to verify that the model simulates flows, pressures, and storage facility levels at the locations of the data sources. If the model results do not match provided system data reasonably well, Black & Veatch will document potential reasons for the discrepancies and provide recommendations on how to improve future model calibration efforts.

Phase 3 of the Work Plan will provide the following**:**

1. A reliable hydraulic model for simulation of pressures and water age/water quality evaluations

2. Ability to simulate water source blending

3. Support of disinfection residual and/or other kinetic water quality parameters simulation

5.3 FUTURE PHASES

The extent of the hydraulic model developed under the current Work Plan will sufficiently meet the anticipated near-term needs of the system. The hydraulic model will have the flexibility to expand beyond that to meet other future needs that MWDOC and its Member Agencies will encounter. Future phases anticipated for the Hydraulic Model would potentially include:

- Additional model calibration efforts as needed to support future system evaluations
- Incorporation of additional water demand conditions/scenarios
- Merging with existing member agency hydraulic models to allow more comprehensive "source to tap" system investigations
- Many other hydraulic and water quality system investigations

By establishing a complete, calibrated model, the Hydraulic Model will be able to support MWDOC's on-going needs of operational coordination, emergency planning, reliability/supply optimization, and AMP outage planning.

6.0 Summary

This report documents the evaluation of various hydraulic modeling software options that are available in the market. The review analyzed the technical capabilities of each model in accordance with MWDOC's goals/needs. From the initial review process, there were four software options that scored high based on their technical capabilities. After the additional "non-technical" criteria were considered, the recommended software selection is **InfoWater by Innovyze**. A Work Plan has been developed to successfully incorporate model build and calibration for Hydraulic Model using InfoWater software.

7.0 Appendices

7.1 APPENDIX 1: MWDOC WHITE PAPERS 2019

MWDOC NEW LOCAL WATER SUPPLY INTEGRATION INTO THE METROPOLITAN WATER DISTRICT SYSTEM UTILIZING THE EAST ORANGE COUNTY FEEDER NO. 2

B&V PROJECT NO. 401798

PREPARED FOR

MWDOC

1 OCTOBER 2019

BLACK & VEATCH

Reviewed by: ______________________________ ______________

Signature **Date**

____

Printed Name

Reviewed by: ______________________________ ______________

Signature **Date**

____

Printed Name

Professional Engineer: ______________________________ ______________

Signature **Date**

____

Printed Name

____

License No.

Approved by: ______________________________ ______________

Signature **Date**

____

Printed Name

Table of Contents

Project Background

Municipal Water District of Orange County (MWDOC) is currently supporting development of several potential new water supply projects to be located in and serve Orange County. These potential new supplies include:

- Ocean desalination from the Huntington Beach Desalination Plant (HBDP). This project is being pursued by a private developer, Poseidon Water.
- Ground water from the Orange County (OC) groundwater basin (groundwater pump back). A number of concepts are under consideration involving a variety of MWDOC Member Agencies and Orange County Water District (manager of the OC Basin).
- Ocean desalination from the Doheny Desalination Plant (DDP). This project is being pursued by South Coast Water District.

If implemented, these new supplies will enhance water supply reliability for the region by providing locally controlled sources of supply that have less risk of interruption.

It is envisioned that water from these sources will be conveyed to MWDOC Member Agencies and possibly other retail water agencies in OC through a combination of new and existing conveyance facilities. The existing conveyance facilities currently convey treated imported water provided by Metropolitan Water District of Southern California (Metropolitan).

Introduction of new water supply sources into this system may require improvements to the existing infrastructure to allow water to flow in different directions than for which it was originally designed, to manage new system operations and hydraulics, and to support management of water quality. Since these new supply sources will have different water quality attributes than the current supplies, it is critical to identify any potential impacts this could have on a variety of fronts: regulatory compliance, downstream facilities, customers, conveyance system materials, and so on.

To establish a work plan for addressing both physical infrastructure needs and impacts of water quality differences, MWDOC has retained Black & Veatch and Hazen and Sawyer to prepare White Papers on these topics. These White Papers have slightly different areas of focus. This Black & Veatch White Paper focuses on the integration issues associated with the HBDP and groundwater pump back concepts described earlier, with a particular focus on the concept of utilizing the East Orange County Feeder No. 2 (EOCF2) as a means of introducing these supply sources into the OC distribution system. That said, many of the concepts described herein also are universal to integration of new water supplies into existing systems, and thus are applicable to the DDP and other concepts.

1.0 Brief Physical Description of Area

An overview of the project and potential issues associated with it are presented in this section. Included is an introduction to the project, project area, and potential impacts related with integration of the proposed HBDP and groundwater pump back to the MWDOC system.

1.1 DESCRIPTION OF SITES, INCLUDING METHOD OF ONTAKE AND OUTFALL

In 2018 MWDOC prepared an OC Water Reliability Study. The OC Water Reliability Study considered multiple paths to improving water supply reliability based upon a number of conceptual projects to make informed decisions on project investments. Two of the proposed projects are included in the scope of this white paper analysis, which include (1) Ocean desalination from the Poseidon Huntington Beach Project and (2) Ground Water Pump back from the OCWD ground water basins. The Doheny Ocean Desalination project is analyzed in the Hazen Sawyer companion white paper analysis. The features and project components for each of these local OC Water supply projects are provided in the Appendix of the OC Water Reliability Study. Figure 1-1 provides an overview of the proposed locations of these Projects and the EOCF2. There are other local supplies that may be integrated into the regional or sub-regional distribution systems, such as the San Juan Watershed Project, but these have not been evaluated herein.

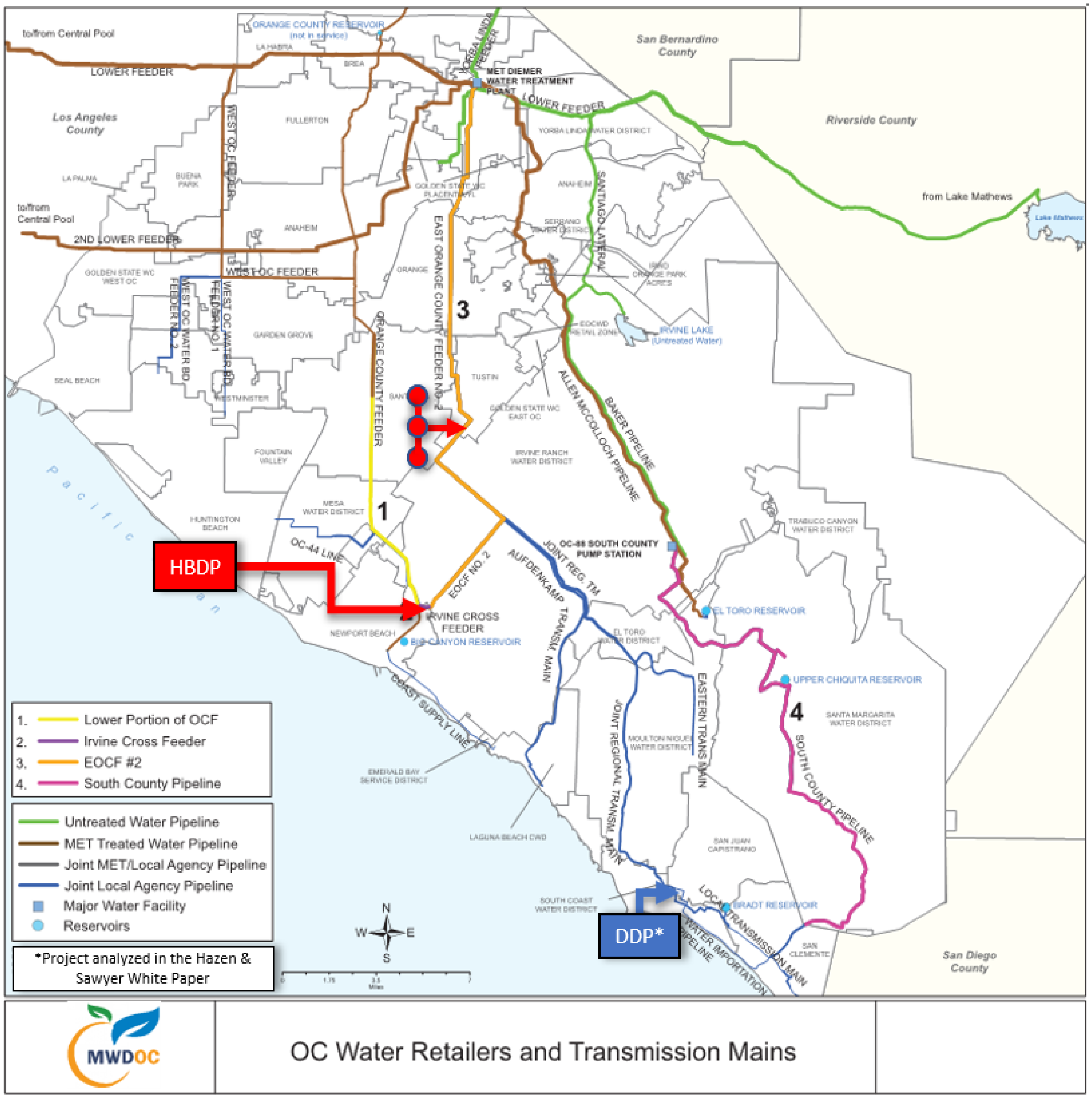


Figure 1-1. Location of the DDP, HBDP, OC basin wellfield and the EOCF2

Huntington Beach Desalination Facility

The HBDP will be co-located at the Huntington Beach power plant, a facility owned and operated by AES Corporation and located at 21730 Newland Street, Huntington Beach. The proposed HBDP would produce 50 million gallons per day (MGD) of potable water for distribution to the OC water system. This White Paper focuses on the concept that water will be delivered to OC customers via the EOCF2 transmission main.

The existing ocean intake at the Huntington Beach power plant would be used to supply seawater to the HBDP. The intake may be required to undergo retrofits in accordance with California Coastal

Commission requirements. The brine discharge will likely be routed into the ocean outfall; retrofit and improvements are likely to be planned by Poseidon Water.

In general, the HBDP source water reliability is subject to red tide algae bloom events, which have been common occurrences in the ocean waters along the southern California coastline. Previous studies performed for West Basin Municipal Water District have included evaluation of biotoxins. Reverse osmosis technology has proven to consistently remove toxins, demonstrating that effluent quality would not likely be impacted by these red tide events. MWDOC should require that Poseidon perform additional engineering studies related to seawater red tide events and evaluate the performance of the HBDP selected treatment technology.

A brief description of the HBDP intake and outfall system is provided in Table 1-1.

Table 1-1. Huntington Beach Desalination Plant Intake and Outfall Facilities

FACILITY	DESIGN CRITERIA
Seawater Intake	1. Subsurface seawater intakes, or for projects where subsurface intakes are infeasible, the facilities would operate an open-ocean intake with 0.5 mm screens with a 0.5 fps approach velocity as best available technology
Seawater Discharge	1. Increased salinity at the mixing zone boundary should not exceed the lesser of 5% of background or 2 parts per thousand; 2. Discharge must meet the salinity standard within 100 meters from the point of discharge. 3. Establish a rebuttable presumption that a multiport brine diffuser system is the best available technology for the disposal of concentrated seawater.

Source - Poseidon Water State Resources Control Board Desalination Policy, 2013.

Groundwater Pump Back

Groundwater pump back will be comprised of installation of new groundwater wells or use of existing wells in the OC Basin. Several concepts are under consideration. One includes installation of new production wells at the Irvine Ranch Water District Dyer Road Wellfield, located near the southern end of the EOCF2. Other concepts would locate new wells in close proximity to the EOCF2, but farther north in the OC Basin. The OC Water Reliability Study included a concept involving installation of three groups of new wells with a capacity of approximately 10 mgd. To date, none of the concepts have been fully defined.

Under normal conditions, it is envisioned that these new groundwater production wells would be used to deliver water directly to retail water agencies in their vicinity. Under drought or emergency conditions, these wells would be called on to deliver water into the OC distribution system via EOCF2 to augment imported supplies. As defined in the OC Reliability Study, a series of such wells would provide water to South OC during an unplanned outage. South OC agencies would then also be required to replenish the groundwater that was taken from the OC Basin through a water exchange.

1.2 SOURCE WATER QUALITY AND COMPARISON TO OTHER SOURCES

All proposed product waters considered for this project are suitable for potable water use and do not exceed either primary or secondary Maximum Contaminant Limits (MCL) set forth by the EPA or the State of California. A comparison of average constituent concentrations for each source water is presented in Table 1-2.

Table 1-2. Comparison of Average Constituent Concentrations in Regional Groundwater, Diemer WTP, HBDP, and Carlsbad Desalination Plant

PARAMETER	AVERAGE REGIONAL GROUNDWATER[1]	DIEMER WTP[2]	HBDP (TSM)[3]	HBDP (CDP)[4]
Chloride (ppm)	80	50 - 103	75	77
Sodium (ppm)	63	51 - 103	60	52
TDS (ppm)	441	294 - 654	350	233
Calcium (ppm)	81	28 - 76	20	24
Magnesium (ppm)	19	12 - 27	N/A	0.7
Alkalinity, as $CaCO_3$ (ppm)	176	61 - 120	N/A	60
Hardness, as $CaCO_3$ (ppm)	279	119 - 296	N/A	53
pH	8	8.1 - 8.4	7.0 - 8.0	8.5
Boron (ppm)	0.1	0.1	0.75	0.59
Bromide (ppm)	<0.1	N/A	N/A	0.4*

Source: 1. 2017 Regional Groundwater Annual Water Quality Report Averages
2. 2016/2017 Metropolitan Annual Water Quality Report Averages
3. Poseidon/OCWD June 2018 Term Sheet Agreement Average Over Sampling Period
4. 2017 Carlsbad Desalination Plant Consumer Confidence Report Averages
**CDP Contract Central Tendency Limit*

Groundwater constituent concentrations presented in this report are based on water quality reports obtained from the City of Tustin, City of Santa Ana, East Orange County Water District (EOCWD), Irvine Ranch Water District (IRWD). Table 1-2 presents calculated average groundwater constituent concentrations based on these four water providers.

Diemer WTP water quality presented in this report is based on a range of constituent concentrations experienced when the treatment facility's source water fluctuates between the State Water Project (SWP) and Colorado River Aqueduct (CRA) water. Diemer WTP regularly treats a blend of SWP and CRA waters that varies in makeup based on water availability changes throughout the year.

Water quality concentrations for the HBDP are based on two sources in this report: the 2018 Poseidon/OCWD Term Sheet Agreement (TSM) and the Carlsbad Desalination Plant (CDP) 2017 average product water concentrations. CDP water quality values may better represent actual HBDP constituent concentrations than the values presented in the TSM because the CDP and HBDP have nearly identical designs and end uses. While the TSM represents actual agreed upon constituent concentrations for the HBDP, the TSM represents mean and maximum values that may not be representative of the actual operating conditions for MWDOC supply. Both historical CDP water quality and the OCWD/Poseidon term Sheet Agreement Water Quality are referenced throughout the report.

A detailed discussion of water quality of each water source and the impacts that integration of HBDP and groundwater pump back water will have on the system and end users is presented in Section 3.

1.3 EXISTING INFRASTRUCTURE

This section provides an overview of existing infrastructure and how it relates to HBDP and groundwater pump back integration.

1.3.1 Storage Tanks

Metropolitan owns and operates five treatment plants which allow for product water storage that are located throughout Metropolitan's service area and that treat water delivered from the State Water Project and the Colorado River. Four of these plants, F.E. Weymouth, Robert A. Skinner, Robert B. Diemer (Diemer) and Joseph Jenson, provide flow to the water supply grid distribution system.

Water retailers utilize storage tank facilities throughout OC as part of the municipal water distribution infrastructure. Typically, each retailer maintains potable water infrastructure, which includes tanks and reservoirs for water supply and production needs within each service area. These tanks can vary in size, design, and construction; the most common include: reinforced concrete tanks, circular prestressed concrete tanks, circular welded steel tanks, and lined reservoirs with floating cover geosynthetic system.

As currently conceived, water from new local supplies would be conveyed to retail agencies via existing pipelines such as the EOCF2. Retail agencies receive water from EOCF2 via Service Connections. Whether the source of the water is treated imported supplies as it is now, or new desalinated or groundwater supplies in the future, should not impact the total demands to be supplied; but may result in a reduction of imported water from MET. These changes should not affect how the retail agencies manage their systems from a volumetric standpoint.

The concern for all parts of the distribution system, inclusive of reservoirs, will lie in management of disinfectant residual, avoidance of disinfection by-product formation, and other water quality concerns due to interaction of desalinated water with existing treated imported water. Details about these potential issues, how to analyze them, and potential means to manage or mitigate impacts are described in Sections 2 and 3.

1.3.2 Distribution System Piping

The Metropolitan system consists of a network of large diameter pipelines that combine to form the "Central Pool" where flow is driven by the individual Service Connection needs. Figure 1-2 provides an overview of the OC Water Distribution System.

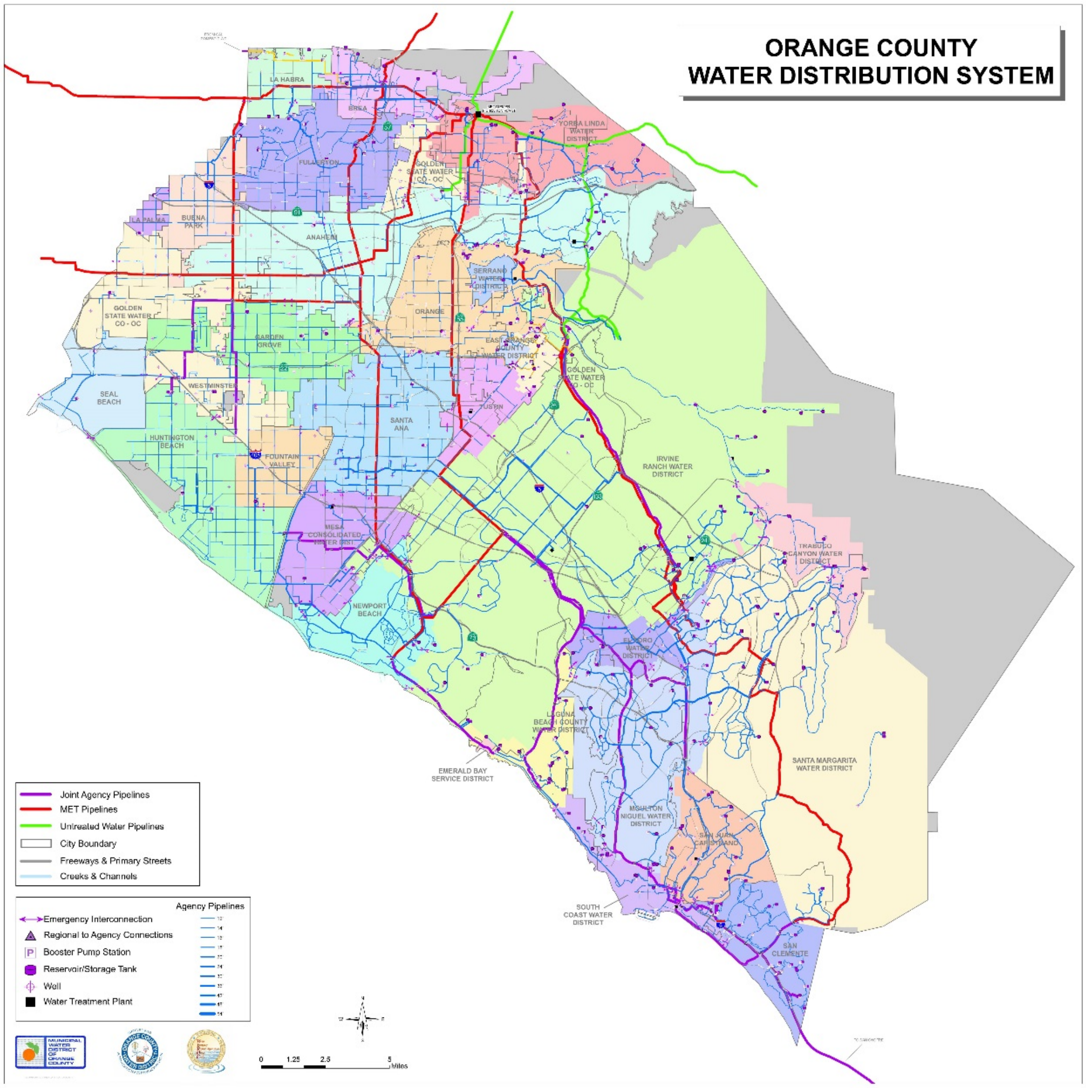


Figure 1-2. Orange County Water Distribution System

Major distribution system piping within the OC area, which are critical to new local water integration as described in this White Paper, include:

- EOCF2
- Orange County Feeder
- Irvine Cross Feeder
- South County Pipeline
- Joint Transmission Main (JTM)
- Aufdenkamp Transmission Main (ATM)

Table 1-3. List of Major Regional Distribution Transmission Lines and Abbreviations

TRANSMISSION LINE	ABBREVIATION
East Orange County Feeder #2	EOCF#2
Orange County Feeder	OCF
Irvine Cross Feeder	ICF
Joint Transmission Main	JTM
Aufdenkamp Transmission Main	ATM
Eastern Transmission Main	ETM
Allen McColloch Pipeline	AMP
Water Importation Pipeline	WIP
OC 44 Line	OC44

1.3.3 East Orange County Feeder No. 2

According to the EOCF2 operation manual, the fourth and final reach extends approximately five miles from the Coastal Junction Pressure Control Junction Structure, through Irvine Ranch to the terminus at the San Joaquin Reservoir. Since the San Joaquin Reservoir has been transferred to the Irvine Ranch Water District, the reservoir inlet and outlet has been bulk-headed and isolated from the EOCF2 system. Despite normal condition isolation, the EOCF2 can still overflow into the San Joaquin Reservoir via an existing air gap. Table 1-4 presents a summary of the key hydraulic design criteria for the EOCF2. This reach has a design capacity of 92.5 cfs and is constructed of 54-inch inside diameter welded steel pipe. It is designed on a falling hydraulic grade line basis to withstand maximum hydraulic elevation varying from 620 feet immediately downstream of the control structure to 477-ft. at the San Joaquin Reservoir.

Table 1-4. EOCF2 Design Criteria Table

DESCRIPTION	CRITERIA
Flow Rate, Q	92.5 CFS
Internal Diameter	4 ft -6 inch
Coastal Junction Structure	Sta 1009+57
Irvine Cross Feeder	Sta 1239+62
Bulkhead (Reservoir Inlet)	Sta 17+80
Max Hydraulic Gradient, H.G.L	477.0 – 620.0
Design Hydraulic Gradient, H.G.L	477.0 – 528.4
Pressure Setpoint @ 1095+95	485 FT
Maximum Allowable H.G.L at Irvine Cross Feeder	495 FT

A hydraulic evaluation for delivery of new supply water to the EOCF2 is needed to ensure that new flow scenarios and resulting pressures meet the original design criteria and allow for continued operation of the water distribution system and address potential impacts on existing facilities.

Currently, the EOCF2 lower reach hydraulic elevation must be kept below the max elevation range of 620 - 477 feet in Reach 4 (below Coastal Junction Pressure Control Structure), based upon the falling design hydraulic grade line elevations. The new water supply integration project would likely need to maintain hydraulic settings below the 477.0 elevation setting within EOCF2, Reach 4. Another key existing feature in the EOFC2 is located at Station 1258, which has a blow off structure at grade elevation 467.0 located near the product water line of the San Joaquin Reservoir.

Table 1-5 presents an overview of the EOCF2 pipe data. Additional evaluation could be focused on the lining material and determining pipe wall thickness. Additional records research and analysis is recommended to determine the actual lining thickness, lining supplier and mix design specification. Additional Metropolitan historical records review could include construction lay-drawings, construction historical contract records (Specs 639, 650) to determine the contractor, pipe supplier, and detailed record drawings review.

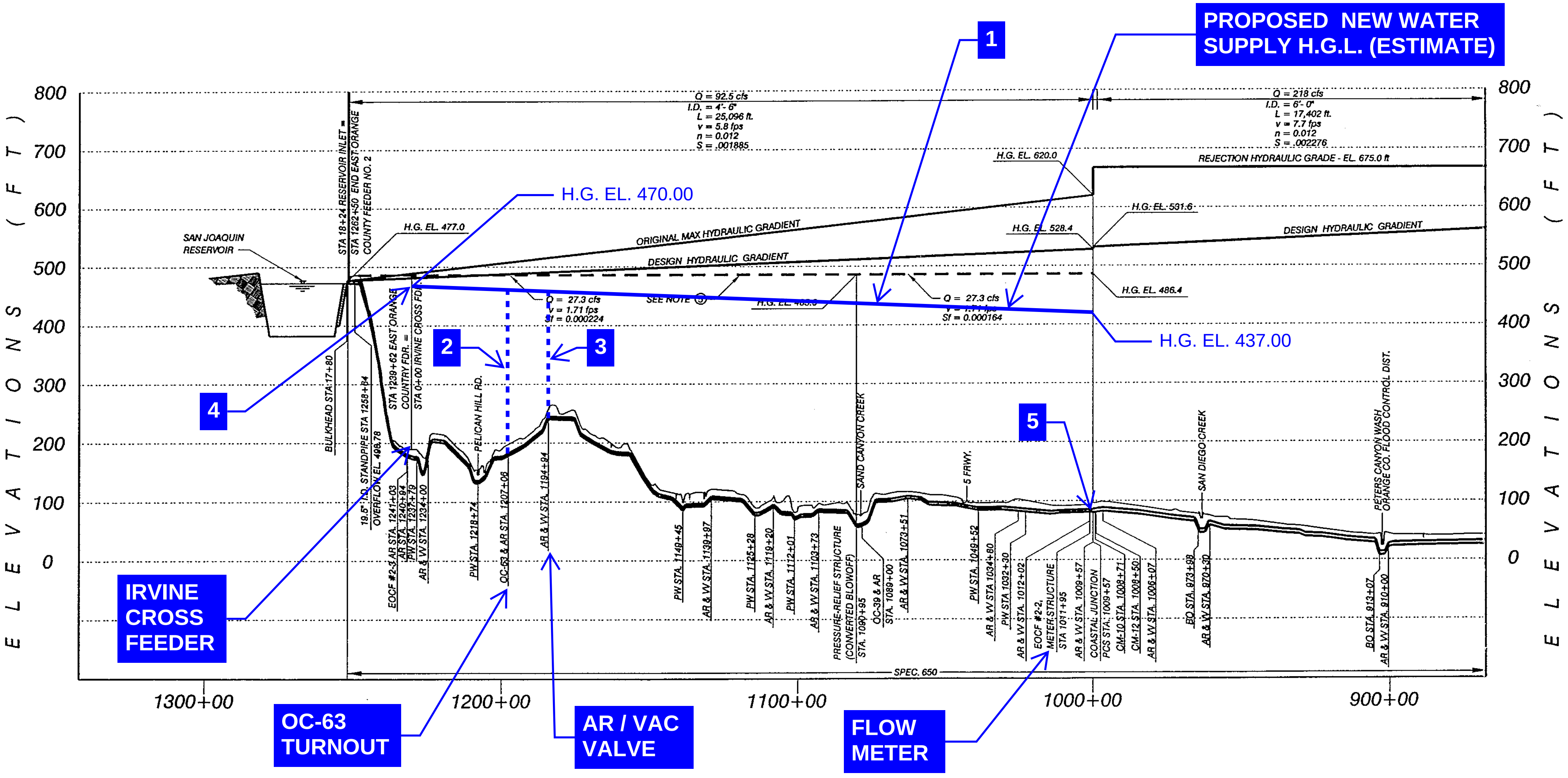
Table 1-5. East Orange County Feeder No. 2 Construction Pipe Data

STATION TO STATION	SPEC.	CONT.	SCHED.	LENGTH.	ID	TYPE	JOINT	LINING	COATING
0+00 to 290+00	639	833	82SC	5.2	78”	W.S	Weld	Mortar	Gunite
290+00 to 550+00	639	833	83SC	4.9	78”	W.S	Weld	Mortar	Gunite
550+00 to 832+13	639	833	84SC	5.2	78”	W.S	Weld	Mortar	Gunite
823+13 to 1009+09	650	843	85SC	3.4	72”	W.S	Weld	Mortar	Gunite
1011+36+1262+50	650	843	86SC	5.0	54”	W.S	Weld	Mortar	Gunite
0+00 to 15+33	650	843	86SC	0.4	60”	W.S	Weld	Mortar	Gunite

Figure 1-3 presents the key hydraulic considerations when delivering water to the EOCF2.

EOCF2 HYDRAULIC CONSIDERATIONS

1. PROPOSED DESIGN HYDRAULIC GRADIENT SHALL NOT EXCEED THE ORIGINAL DESIGN HYDRAULIC GRADIENT
2. MAINTAINING ADEQUATE PRESSURE FOR EXISTING TURNOUT/SERVICE CONNECTIONS
3. EVALUATE PRESSURE CONDITIONS FOR ALL EXISTING AIR RELIEF / VACUUM VALVE ASSEMBLIES
4. IMPACTS TO INTERCONNECTION FACILITIES
5. IMPACTS TO FLOW METER DEVICES RELATED TO FLOW REVERSAL



EAST ORANGE COUNTY FEEDER NO. 2 PROFILE (REACH 4)

Figure 1-3. Key Hydraulic Considerations to Delivery of Water to EOCF2

When delivering new water supply to EOCF2, additional hydraulic factors also need to be considered, which include:

Maximum hydraulic elevation settings. Review detailed hydraulic plans, discuss with operations the procedures for use in the day to day operations of feeders, turnouts, PCF, and interconnection facilities.

Maintaining adequate available pressure at turnouts. Each turnout along the EOCF2 contains a valve and flow meter device for flow metering and billing to member agencies. Impacts to the upstream pressures and flows need to be modelled and evaluated to ensure that upstream, downstream, and pressure differentials are within the turndown specification requirements of the existing valves.

Air relief and vacuum valve facilities. The operating pressure conditions may impact the vacuum valve facilities. The air relief and vacuum (ARV) valve components, basis of design and recommended hydraulic settings should be reevaluated. In some cases, if pressure conditions are lowered, the valves may not properly seat and could cause leaking conditions at the ARV assemblies. Conversely, if pressure conditions are higher than the design rating, then the valve recommended settings and seat material may need to be re-evaluated.

Impacts to interconnection facilities. The Irvine Cross Feeder is a 42 -inch diameter prestressed concrete pipeline which links the East Orange County Feeder No. EOCF2 with the Orange County Feeder. It is ½ mile long and has a design capacity of 75 cfs and is designed to withstand a maximum hydraulic pressure of *485 feet (*495 feet according to the EOCF2 general notes – profile drawing). Its primary purpose is to convey water westerly directly from the EOFC2 to the OC feeder to augment flow in that feeder. It is capable of reverse flow scenarios under unusual operating conditions. The Irvine Cross Feeder is connected at EOCF2 Station 1239+62. The new water supply would have impacts to the interconnection (such as the Irvine cross feeder) to evaluate operation and hydraulics impacts and layout of Metropolitan pipelines are shown in Figure 1-4.

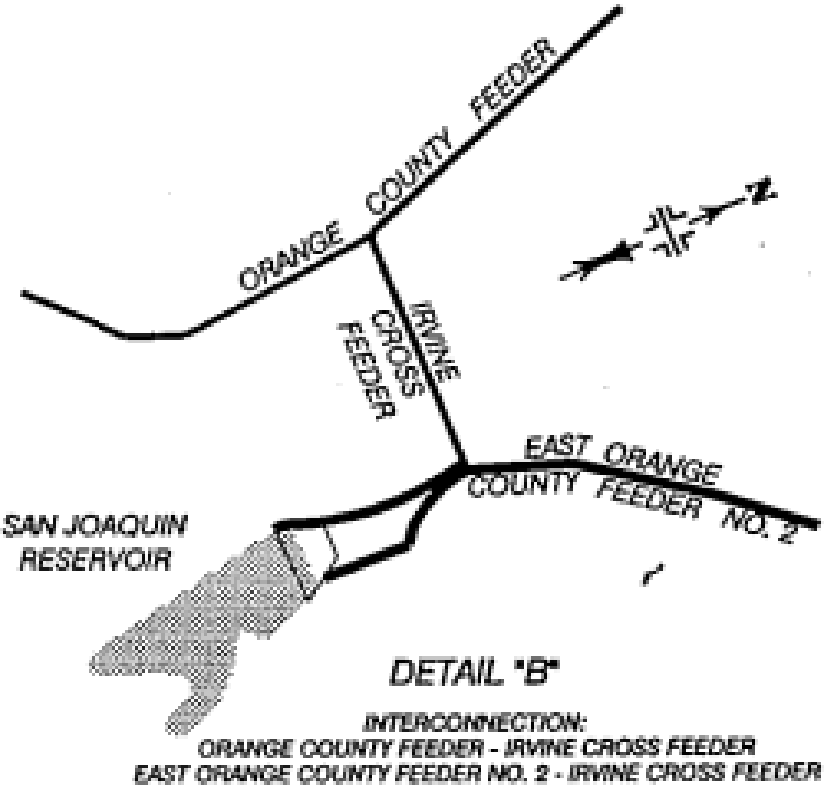


Figure 1-4. Detail of the interconnection of the Orange County Feeder, Irvine Cross Feeder, and East Orange County Feeder No. 2.

1.3.4 Flow Control

The flow of product water into the EOCF2 is from the clearwell at Diemer Water Treatment Plant located in Yorba Linda. The current EOCF2 distribution system includes pressure control facilities, such as the Santiago Creek P.C.S. and Coastal Junction P.C.S., but is controlled via downstream flow control structures (Service Connections) delivering water to various agencies.

Santiago Creek P.C.S.

The water flow rate in the upper reaches of EOFC2 is controlled by regulating facilities at the Santiago Creek Pressure Control Structure. This control facility is located nine miles south of the Diemer Plant on the east side of Tustin Avenue, just south of Chapman Avenue in the City of Orange. The Santiago Creek Pressure Control Structure contains 10 branch lines through which water can be delivered. The Metropolitan operations manual has a detailed description of the motor-operated regulating valves, shut-off isolation valves, pressure relief valves and relief lines which connect to a 48-inch discharge line that connects into a dissipating structure adjacent to the Santiago Creek Channel.

Coastal Junction P.C.S

The Coastal Junction Pressure Control Structure is located approximately 11 miles downstream of the Santiago Creek P.C.S. on Barranca Road in Irvine. This structure contains hydraulically-operated regulating valves used for precise flow control; they also serve as pressure relief valves.

The dual function valves are possible because the upstream pressure relief is made directly into the feeder immediately downstream of the structure. The upstream and downstream line pressures are monitored through centralized control facilities at the Diemer Plant.

In 2016, Black & Veatch assisted MWDOC by preparing several design concepts for integration of HBDP or groundwater pump back into the EOCF2. These concepts investigated potential physical points of connection to the EOCF2, while identifying the Service Connections that would need to be served in order to consistently utilize all 50 mgd of water from HBDP during all parts of the year (i.e. accounting for demand fluctuation). Concepts included connecting the HBDP to the southern end of the EOCF2, then pumping it northward to reach a sufficient number of Service Connections to consistently utilize 50 mgd. Such a concept would require bypassing the aforementioned Pressure Control Structures, which is to say, the manner of operating the EOCF2 would completely change.

1.4 DESCRIPTION OF TYPES OF POTENTIAL IMPACTS

This section provides a description of the potential impacts associated with the integration of the HBDP and groundwater pump back into the MWDOC system.

1.4.1 Materials of Construction

Different pipe materials in drinking water distribution systems are commonly used throughout OC. The list below provides the material types commonly found in the vast distribution network, which includes regional conveyance systems, water agencies, city water utilities, and private residential, commercial, and industrial users.

- Prestressed Concrete
- Cement Mortar Lined Steel
- Concrete Cylinder
- Ductile Iron
- Asbestos Cement
- Prestressed Concrete
- Iron
- Steel
- Copper
- PVC
- HPDE

The major concern for pipeline materials, including those listed above, is the corrosion potential of source water qualities. The introduction of a new water source can create a change in water quality that can induce leaching of pipeline materials. Leached pipe material particles can pose serious health risks and lead to significant degradation of the transmission system. Anticipated impacts on conveyance system materials and linings from the integration of the HBDP and groundwater pump back are discussed in depth in Section 3.10 and 3.11.

1.4.2 Water Quality of Blending Sources

The HBDP and groundwater pump back product waters will impact the overall water quality of the blended system by changing concentrations of a variety of constituents in the system. HBDP and groundwater pump back waters have potential to marginally increase Total Dissolved Solids (TDS) concentrations in the system when the Diemer WTP is supplied by primarily SWP water. However, because average TDS concentrations of both the HBDP and groundwater pump back are less than the average Diemer WTP TDS concentration, changes in TDS are expected to be marginal. Diemer TDS values can have a significant range due to source water quality and changes in the percentage of each MET source water at the blended water treatment plants. The range of TDS values from the HBDP are significantly less due to the nature of its source water (Pacific Ocean seawater) and the nature of membrane treatment (100% of the source water receives membrane treatment).

A particular concern for the addition of HBDP water to the system is the elevated concentrations of boron in desalinated water. Boron concentrations in the planned HBDP water do not exceed drinking water standards but do pose a risk for agriculture/horticulture and certain environmental goals of the region. A discussion of water quality concerns associated integration of the new water supplies as well as recommendations for next steps to address water quality concerns is presented in Section 3.

1.4.3 End Uses and Facilities Impacted

A discussion of impacts on end users and facilities associated with integration of the HBDP and groundwater pump back is presented herein.

1.4.3.1 Groundwater Replenishment

There are two primary aquifers within the MWDOC service area, the Coastal plain of Orange County groundwater basin (OC Basin) and the San Juan Valley groundwater basin (San Juan Basin). The San Juan Basin covers about 17,000 acres and primarily spans portions of Dana Point, San Juan Capistrano, and Mission Viejo. Due to the relatively small storage capacity of the aquifer, local groundwater production only makes up about 5% of south OC's potable water supply. The San Juan Basin is currently only replenished by natural percolation, primarily by San Juan and Trabuco Creek. However, multiple groundwater replenishment projects have been considered recently, including a stormwater recharge project and a recycled water recharge project.

The OC Basin spans the majority of north and central OC and covers roughly 224,000 acres. The basin serves about 2.4 million residents and supplies roughly 70% of potable water for the 19 water retailers in the region. The OC Basin has one of the most robust recharge systems in the world. OCWD operates a sophisticated recharge system that includes recharge of the basin with natural runoff, recycled water, and imported water. OCWD's Groundwater Replenishment System (GWRS) is the largest indirect potable reuse facility in the world and currently produces 100 MGD (expected 130 MGD in 2023) of recycled water used for groundwater replenishment.

As currently conceived, neither the HBDP or the groundwater pump back will have a direct connection to a groundwater recharge project in the region. However, either of these sources could enter into recycled groundwater recharge programs as wastewater. Groundwater pump back is not expected to have an impact on recharge projects of this kind because it is already a source water for homes whose wastewater serves the only recharge program in the region currently in operation, GWRS, without issue. The impacts of HBDP water entering recycled water treatment facilities such as GWRS is not anticipated to have negative impacts on recycled water treatment processes, due to the overall high quality of the HBDP water. Non-organic constituents targeted in treatment facilities like GWRS such as TDS and hardness are present in lower concentrations in HBDP water compared to regional groundwater and Diemer water, making HBDP water less intensive to treat. Water quality impacts of the HBDP and groundwater pump back on recycled water treatment facilities (including groundwater recharge treatment facilities) are discussed further in section 3.8.

Implementation of HBDP water into MWDOC's system has the potential to impact groundwater pumping rates for member agencies in the OC Basin based on MWDOC's agreements with individual member agencies. The addition of groundwater pump back could have a direct impact on groundwater in the OC Basin through the extraction of groundwater in the southern portion of the OC Basin. The proposed groundwater pump back wells have the potential to lower the groundwater table within their immediate vicinity based on the pumping rates of each well. However, drawdown is not expected to be substantial as the groundwater pump back wells will only operate under emergency situations and will have a maximum flowrate of 50 cfs for no more than 60 days. Potential physical impacts to groundwater associated with HBDP and groundwater pump back are discussed further in Section 2.5.1.

Groundwater quality has the potential to be directly impacted by HBDP water through incidental percolation of landscaping and irrigation water and recycled water recharge systems. Water quality parameters in desalinated water have the potential to change the makeup of constituents in local groundwater supplies based on the volume of desalinated water being infiltrated or recharged. Potential water quality impacts to groundwater associated with the HBDP and groundwater pump back integration are discussed further in Section 3.7.

1.4.3.2 Agriculture & Horticulture

Orange County currently has an approximate $110,000,000 agricultural industry (OC Public Works, 2017). 55% of OC's agricultural value comes from nursery agriculture, which includes non-edible flowers, shrubs, succulents, and trees. Vegetable, field crops, tree fruit, and berry production roughly make up the other 45% of OC's agricultural value and cover roughly 19,000 acres within OC. Agricultural irrigation is currently supplied by both potable and reclaimed water sources. Integration of HBDP water has the potential to impact the quality of water provided for irrigation through direct supply of potable water or end use integration to the recycled water. Integration of groundwater pump back is expected to have a minimal impact to agriculture due to its already extensive use in OC, where no significant impacts are observed in the areas that are irrigated directly with 100% groundwater.

For the purposes of this report, horticulture is defined as small scale gardening and non-food producing plants. Horticulture generally refers to plants and landscaping throughout the MWDOC service area that are not sold commercially. Potential water quality impacts to agriculture and horticulture associated with HBDP and groundwater pump back integration are discussed further in Section 3.6.

1.4.3.3 Recycled Water Treatment Facilities

Recycled water within MWDOC's service area is produced by 6 primary agencies: OCWD, Irvine Ranch Water District (IRWD), South Orange County Wastewater Authority (SOCWA), Santa Margarita Water District (SMWD), El Toro Water District (ETWD), and Moulton Niguel Water District (MNWD). A brief description of each agency's recycled water program followed by a summary of potential impacts is described below.

OCWD

OCWD currently produces two forms of recycled water. OCWD's Green Acres project produces 3 MGD (7.5 MGD capacity) of Title-22 disinfected tertiary recycled water for irrigation throughout Costa Mesa, Huntington Beach, Santa Ana, Fountain Valley, and Newport Beach. OCWD's GWRS produces 100 MGD (130 MGD Final Expansion in 2023) of Title–22 fully advanced treated water suitable for indirect potable re-use. About one-third of GWRS product water is delivered to 23 injection wells along the coast and two-thirds is percolated into the groundwater in recharge basins.

IRWD

IRWD currently produces a total of 25 MGD of Title–22 disinfected tertiary recycled water at its Michelson Water Recycling Facility in Irvine and Los Alisos Water Recycling Plant in Lake Forest. IRWD's recycled water program provides reclaimed water for landscaping, agriculture, and select industrial processes throughout its service area.

SOCWA

SOCWA currently produces over 6 MGD of Title-22 disinfected tertiary recycled water at its Regional & Coastal recycling facilities in south Orange County. Recycled water produced by SOCWA is used primarily for irrigation of landscaping, filling recreational lakes, and select industrial processes.

SMWD

SMWD currently produces roughly 10 MGD of Title–22 disinfected tertiary recycled water at its Chiquita Water Recycling facility in Santa Margarita and its Oso Water Recycling Facility in Mission Viejo. Recycled water is used for irrigation and for filling Lake Mission Viejo.

ETWD

ETWD currently has capacity to produce roughly 3.7 MGD of Title–22 disinfected tertiary recycled water at its El Toro Water Recycling Facility in Laguna Woods. Recycled water produced by ETWD is used for irrigation purposes.

MNWD

MNWD currently produces roughly 2.4 MGD of Title–22 disinfected tertiary recycled water at its 3A Water Reclamation in Mission Viejo. Recycled water produced here is used irrigation purposes.

A summary of south County treatment plants that produce over 1 MGD of recycled water is presented in Table 1-6.

Table 1-6. SOCWA & SOCWA Member Agency Recycled Water Facilities with Over 1 MGD Recycled Water Production

RECYCLING FACILITY	WASTEWATER COLLECTION AGENCY	RECYCLED WATER PRODUCTION CAPACITY
Regional Treatment Plant	SOCWA	5 MGD*
Coastal Treatment Plant	SOCWA	1.1 MGD*
El Toro Water Recycling Plant	El Toro Water District	3.7 MGD
Oso Water Reclamation Plant	Santa Margarita Water District	3 MGD
Chiquita Water Reclamation Plant	Santa Margarita Water District	6 MGD
3A Water Reclamation Plant	Moulton Niguel Water District	2.4 MGD
**Average recycled water production*		

Any impacts to recycled water treatment facilities in the region as a result of the proposed integration are expected to be primarily from desalinated water. Because groundwater is already a potable water source in both basins and the expected increase in groundwater supply is minimal, the proposed groundwater pump back is expected to have a negligible impact on the wastewater feeding the water recycling facilities. The integration of desalinated water may, however, have an impact on the water quality fed to recycled water programs. Increases in influent constituent concentrations, such as boron, at water recycling plants have potential to impact recycled water facilities' discharge permits. Anticipated water quality impacts to recycled water treatment facilities associated with the HBDP and groundwater pump back integration are discussed further in Section 3.8.

1.4.3.4 Industry

Industrial and business processes that depend on municipal water have the potential to be impacted through the introduction of new water sources. Industrial water is considered water used to create/manufacture a product, or water used for cooling processes. Both products created in industry and cooling towers can be sensitive to constituents present in water. Industries that have processes that are particularly sensitive to certain constituents often have their own onsite pre-treatment to remove constituents of concern. For example, many industries that use cooling water to cool boilers employ scale-removing technologies, such as ion-exchange or RO, to remove excess hardness and/or TDS prior to introduction to the system. Integration of the HBDP and groundwater pump back are not expected to cause any negative impacts to industry due to TDS because HBDP and groundwater pump back both contain average TDS concentrations below that of Diemer WTP. Industries that see increased levels of HBDP water are actually expected to see decreased TDS loading on their system. While TDS is a common concern among many industrial users, individual industrial users may have specific constituents of concern for their processes.

In a recent case study on the integration of the Carlsbad Desalination Plant into the San Diego water system published by the Water Research Foundation, it was found that some local brewers were adversely impacted by desalination integration (Alspach & Imamura, 2018). A representative from Stone Brewery stated that they were concerned about the elevated chloride to sulfate mass ratio (CSMR) of desalinated water impacting their product's taste and were updating their facilities to control the impacts. Although this was only a single brewery reporting this, it highlights that different industries will be concerned with a variety of constituents and a select few may need to adjust their processes accordingly.

Industries are expected to see similar or lower TDS concentrations with the integration of either the HBDP and groundwater pump back, based on average TDS concentrations of the water sources. Scaling potential should remain similar to or less than existing conditions with planned post treatment management of the source waters. A small number of industries with special constituent concerns could be adversely impacted and may need to modify pre-treatment processes to their system, but such occurrences are expected to be rare. Investigations by individual businesses and industrial users may be warranted prior to integration of the new water sources to address specific constituent concerns. To address any concerns for all industrial customers, it is recommended that early communication between water providers and businesses/industry be undertaken to address the concerns that customers may have with the integration of desalinated water into their processes. Beyond such communication, Black & Veatch does not recommend any additional studies on this subject.

1.4.3.5 Homeowners

Integration of a new water source into a distribution system can create multiple challenges with residential communities. Major impacts to consider include appliance scaling, corrosion of fixtures, and aesthetics. A summary of each of these topics is presented herein.

Scaling of Appliances

Significant scaling in residential appliances, such as water heaters and fixtures, can result in poor performance of appliances and frequent replacement. Scaling is caused by the accumulation of precipitated calcium and magnesium salts on surfaces in contact with water. The scaling potential of a certain water quality is generally measured using the Langelier Saturation Index (LSI) or Calcium Carbonate Precipitation Potential (CCPP).

Scaling potential for the blended water considered for this project will be primarily dependent on the post treatment processes adopted by the HBDP and the existing groundwater hardness. Existing calcium and magnesium concentrations in groundwater are higher than both Diemer WTP water and desalinated water, which will increase overall scaling potential. Desalinated RO permeate has very low scaling potential and is considered aggressive without treatment. RO permeate is generally post-treated to stabilize the water and to prevent corrosion in the distribution system. If the post-treated water is "over-treated" and LSI and CCPP values exceed 0.5 and 10, respectively, oversaturation and excessive scaling can occur. As discussed further in Section 3.5, adequate post-treatment of the blended water will control whether the water is corrosive or scale forming through the addition of calcium carbonate and management of temperature, pH, and alkalinity.

Fixture Corrosion

Corrosion of household plumbing and fixtures can result in deterioration of fixtures and health risks for consumers. Corrosion is commonly controlled through water quality that promotes scale on pipes. If a water quality is too corrosive (LSI<0 and CCPP<0), leaching can occur.

Leaching of lead and copper pipes is the greatest concern for household corrosion and health risks. Lead and copper, historically common in household plumbing, have become regulated significantly in California due to the US EPA Lead/Copper rule and the California AB1953 Lead Law. These regulations have substantially reduced lead concentrations in household plumbing. The potential for releases of copper and lead have been studied significantly and determined to be manageable with enough calcium carbonate saturation, as found in the four pipe loop studies conducted for desalinated water described in section 3.11.

Many health risks associated with household corrosion have been mitigated by up-to-date laws and replacement of old fixtures. Management of calcium carbonate saturation in the blended water will encourage scale and protect against leaching of plumbing materials. Metal complexation and release has also been linked to high DIC (dissolved inorganic carbon, essentially synonymous with alkalinity) concentrations, making the HBDP less likely to influence metal release as it has lower and adjustable alkalinity.

Corrosive potential for the proposed water sources is discussed further in Section 3.5.

Taste, Odor, and Appearance

Aesthetic quality of water is an important aspect of overall water quality. Consumer satisfaction is important to avoid complaints and public disapproval of a project such as this. Changes in aesthetic aspects of the proposed blended water may have a noticeable difference compared to existing Diemer WTP water. In a study conducted by the San Diego County Water Authority (SDCWA) and McGuire Environmental Consultants, over 70 people participated in a blind taste test comparing desalinated water, imported water sources, and varying blends of both (McGuire et al., 2007). Results from the taste test showed that consumers can differentiate between desalinated water and imported water and generally preferred imported over desalinated water. The study also found that customers could not differentiate between different blends of desalinated and imported water. Another finding of the study was that variances in the alkalinity and hardness of the different waters tested were primary factors in the customers' ability to differentiate between water sources. These findings suggest the potential change in water quality and resultant aesthetics for blended sources from pump back scenarios will be no greater than the changes currently observed in the MET system due to changes in source water quality or blend ratio at the blended water treatment plants.

Changes to the visual appearance of water being integrated with desalinated water can be prevented in the long term with sufficient calcium carbonate saturation as concluded in Trussell Technologies' Technical Memorandum studying water quality requirements for the HBDP. However, there is a chance that a small percentage of customers with unlined iron pipes in their system may experience a "red water" event for a short period following a water source change (Trussell et al, 2016). Red water events are caused by the leaching of iron from unlined iron pipes in the distribution system. Long term leaching can be managed by controlling calcium carbonate saturation in the pipe network, but short-term red water events are sometimes uncontrollable upon integration of a new water source. Only a small percentage of major transmission lines in the MWDOC service area are known to contain iron pipe materials; however, there may be a more substantial amount of unlined iron in local water distribution systems that could lead to a red water event.

From the evidence presented and referenced in this section, long-term impacts to homeowners and residential areas within the MWDOC service area due to the HBDP and groundwater pump back integration can be mitigated with adequate post-treatment management. However, potential for short-term impacts stems from the unknown quantity of unlined iron pipes that may be present in water districts throughout the MWDOC service area. Black & Veatch recommends a survey be conducted of local unlined iron water infrastructure in areas that will see changes in their source water to make a determination as to whether a red water event may have a substantial impact on the public.

Water quality changes are a major concern for many homeowners and can often lead to public opposition if effective communication and marketing is not employed by the water wholesaler and local water agencies. A coordinated public outreach campaign with MWDOC, Poseidon Resources, and local agencies to educate the public would help avoid public opposition to the project.

It should be noted that older residential communities within Orange County were developed in construction phases by home builders which used construction materials and methodologies that are not in compliance with current building codes and regulations such as the Lead and Copper Rule. In particular, there may be regions within Orange County where single-family homes built during the 1940-1950s commonly used galvanized and unlined-iron pipe within the home. MWDOC could perform a home survey investigation to determine home construction practices by decade and identify any specific locations within the Orange County area where potential communities of single-family homes may contain older galvanized or unlined iron pipe. This survey could help make informed decisions during the modelling effort to allow for informed decisions and understanding impacts to these homeowner areas/communities.

2.0 Physical Issues Related to Integration

Physical issues associated with the integration of the HBDP and groundwater pump back systems are presented in this section. Included is a review of potential tie-in locations, flow and pressure control strategies, impacts to conveyance and storage infrastructure, and recommendations for addressing physical concerns in the future.

2.1 POINTS OF ENTRY

This section provides a brief background and overview of planning steps related to point of entry for integration of new water supply into the EOCF2.

2.1.1 Prior Studies

Black & Veatch has performed previous studies for MWDOC in which we provided conceptual level alternatives for introducing desalinated water from Huntington Beach Desalination Facility into the EOCF2. The evaluation assessed potential service connection end-users flow data (YR 2016) and developed conceptual conveyance alternatives to introduce the desalinated water to the EOCF2. This effort included identifying the necessary conveyance facilities, potential points of connection to maximize use of the new water supply by member agencies, and modifications to the EOCF2 that would be required due to the project. Planning level cost estimates were provided.

Other studies have been performed by OCWD and Poseidon Resources on conveyances facilities which included flow scenarios that delivered a portion of the product water to the EOFC2 via the OC-44 pipeline located in Costa Mesa.

The EOCF2 alignment begins in the City of Yorba Linda and extends 25 miles southerly through Anaheim, Orange, Santa Ana, Tustin, Irvine, and City of Newport Beach. Establishing the point of entry of new water supply projects into EOCF2 pipeline segments has been focused on lower segments (Reaches 3, 4) which is primarily due to proximity of the project. Introduction of water into Reach 3 is based on a typically higher level of flows of water from Metropolitan that would allow complete mixing of the two sources of water. The EOCF2 system terminus is located about 12.5 miles away from the proposed HBDP located adjacent to PCH within Huntington Beach.

Multiple factors and considerations are needed to select the optimal point of entry into the EOFC2. Key factors to be included in the evaluation process are:

- Existing Operational impacts
- Engineering (Geological, Civil, Structural)
- Hydraulics
- Metropolitan
- Community
- Permitting / Environmental / CEQA considerations
- Jurisdictional Requirements (Utility ROW, Staging, Traffic Impacts)
- Costs and Construction Schedule
- Future Operation and Maintenance
- Interconnection Pipeline Facilities

2.1.2 Operational Impacts

A key study will be to assess the impact of introducing new water supplies on overall system operation. Of particular importance will be assessing, and resolving any resulting issues associated with, introduction of the HBDP supply into the OC distribution system.

As noted earlier, the HBDP has a planned capacity of 50 mgd. It is desirable to operate desalination plants at a steady rate due to the nature of membrane treatment processes. Further, maximizing the delivery of water from the HBDP will drive down the unit cost of the water. Intermittent changes in flows, and operation of the plant at lower flow rates will drive up the unit costs, making this supply more expensive for MWDOC and its Member Agencies.
The Diemer plant has a capacity of 520 mgd, but currently typically delivers between 200 and 300 mgd on average. Introduction of 50 mgd represents a significant percentage of the total demand currently served by Diemer. DDP water will also have impacts to Diemer, but those impacts will be less severe as DDP's capacity is expected to be between 3 and 15 mgd.

Minimum flow restrictions at the Diemer WTP would limit the HBDP's ability to operate at full capacity in many instances. Diemer WTP's 70 mgd minimum sustainable flow requirement would require HBDP to reduce production anytime demand in the system fell below 120 mgd, a scenario that has occurred over 20% of the time over the last 5 years according to Metropolitan.

Another concern is how facilities will operate in the event of expected or unexpected shutdowns. Diemer's relatively small clearwell (24 mgd) would make sudden shutdowns of the HBDP or groundwater pump back a concern due to the lack of available storage.

A study of operational scenarios and impacts should therefore focus on:

- Defining proposed operation of new supply facilities with respect to production rates and timing.
- Defining how facilities will meet demands in the event of a shutdown of any of the existing or proposed facilities.
- Defining operation of pumping and flow control within the regional distribution system, including changes to pressure and flow management facilities within the existing system.
- Establishing how Diemer would be operated given the new supply sources and their operational parameters, or vice versa, establishing how Diemer operation needs to be accommodated by new supply facilities.
- Determining how Member Agencies would adjust their operations given the new supply sources (as noted earlier, since Member Agencies accept flow from EOCF2 via Service Connections and since HBDP water would be introduced into the OC distribution system via EOCF2, it is expected that new supplies will not impact how they operate their systems so long as water quality issues are fully addressed. Nonetheless, this should be studied and documented).

An important aspect of integration that will drive the ease of operations between these new facilities is the creation of an operating protocol that will define responsibilities between Metropolitan, HBDP, and groundwater pump back operations. The protocol would include definitions of the interface locations between Metropolitan and the HBDP, a communication plan, water quality reporting plan, a maintenance schedule, and an emergency management plan. An Operating protocol should be worked out between Metropolitan, Poseidon, and the groundwater pump back operations sometime following the operational scenarios study.

2.1.3 Infrastructure Requirements

Both physical and water quality constraints will need to be considered for infrastructure related to tie-in of the HBDP and groundwater pump back.

Metropolitan's requirement to maintain a 0.7 mg/L fluoride concentration in their distribution system will require some level of fluoride addition for the HBDP. The groundwater pump back facilities may also be mandated to meet this requirement, however because this will be classified as an emergency water source, MWDOC has expressed interest in getting an exception for the pump back facilities. Fluoride addition requirements for the groundwater pump back facilities will require further discussion between MWDOC and Metropolitan.

In order to avoid the potential for contamination of Diemer water with off-spec water from either the HBDP or groundwater pump back, Metropolitan desires an engineered buffer be set between the new water source's supply and existing facilities. The engineered buffer, commonly a wet well design, is required by Metropolitan to have 4 hours of storage downstream of the treated water source's Critical Control Point (CCP) and to have a route/method to dewater said storage volume in case of an off-spec event. The CCP in a treatment facility can be defined as point(s) in in the treatment process that reduce, prevent, or eliminate a human health hazard and for which controls exist to ensure the proper performance of that process (Hazen, 2019). The CCP is part of a larger methodology known as the Hazard Analysis and Critical Control Point (HACCP) system that acts as an engineered control system to identify and prevent contamination in a system. HACCP is discussed further in Hazen's Desalination Integration White Paper.

In order to meet Metropolitan's desired engineered buffer requirements, both the HBDP and groundwater pump back facilities will need to size a storage system that can retain a volume of water associated with 4 hours of maximum flow downstream of the facilities' CCP. Engineered buffers commonly consists of large storage tanks or wet wells, however, the volume of the transmission pipeline from the treatment facility to the tie-in point can also be counted towards the storage volume required downstream of the CCP as well. The storage systems will also need to be designed to be capable of removal and disposal of a designated volume of water should an off-spec event occur.

Potential considerations for sizing and locating the engineered buffer storage systems for both the HBDP and groundwater pump back facilities will be an important part of the preliminary design process and needs to be considered prior to designating tie-in point(s) along the EOCF2 in order to ensure there is adequate space available for the required facilities.

2.2 FLOW AND PRESSURE CONTROL, FLOW CHANGES, FLOW REVERSALS

Introduction of new water supplies into the OC distribution system will likely result in need to reverse flow in some facilities, depending on where the water is introduced. As described earlier, introduction of HBDP water near the south end of EOCF2 would likely require reversing flow in

EOCF2 to move water northward to a sufficient number of service connections to be able to utilize 50 mgd of flow.

As next steps, Black & Veatch recommends MWDOC perform additional studies and hydraulic flow modelling to further refine a technical evaluation related to flow changes and pressure control issues. In general, the successful integration of new water supply would include key hydraulic and project components based upon evaluating the following items:

- Flow routing based on seasonal and diurnal flow variations
- Current and forecasted flow scenarios vs EOCF2 design capacity and size.
- Forecasted demands of turnout / users and existing Metropolitan Diemer operations evaluation.
- Planning level layout of the point of entry, conveyance pipeline system, break tank (wet wells) and sizing.
- Planning level layout of intermediate pump station size and type.
- Redundancy and reliability requirements of conveyance system.
- Pipeline appurtenances including, air-relief-vacuum, and pressure surge facilities.

As treated water flows through pipelines over time, the interaction of constituents in the water and the lining of the pipe results in deposition of those constituents onto the lining. In pipelines like EOCF2, where water flow has maintained the same direction over time, the adhered constituents are accustomed to that direction of flow. If flow is reversed, such as in the HBDP to EOCF2 concept, it is possible that the adhered constituents could be disrupted and go back into the water. It is also possible that changes in water chemistry can cause the adhered constituents to dissolve and go back into the water. Such changes could result in changes to the aesthetics of the water (taste, odor, color, etc.) that could be alarming to customers.

The aforementioned hydraulic model would be used to determine the locations and extents of flow reversals. From that, it is recommended that a follow-on study be performed to determine an appropriate approach to mitigating this concern.

2.3 TRANSIENT MANAGEMENT AND IMPACT OF LOSS OF POWER

Pipeline transients are defined by a rapid drop in flow rate, accompanied by a spike sudden change in pressure, potentially leading to over-pressurization or vacuum conditions which can damage pipelines, valves, and other appurtenant systems. In a worst-case scenario, such events could be so damaging as to result in leaks or ruptures of key distribution system components, resulting in damage to public or private property in areas surrounding the damaged systems.

A detailed pipeline surge analysis is required to evaluate the proposed hydraulic scenarios and review the entire network of pipelines and impacts to the EOCF2. Pressure surges can cause significant damage to pipelines and other conveyance facilities including pump cans and damages to pipeline appurtenances. Based upon the surge studies, adequate surge protection will provide mitigation measures for conveyance pipeline and pump station facility planning.

The primary objective of the surge evaluation is to define the system facilities and flow characteristics through modelling. Pressure surge analyses are typically run to understand transient conditions during unsteady state hydraulic operation events such as a pump failure or pump start operations based upon predicted maximum and minimum pressures in the system.

The recommendations of the surge evaluation typically provide pipeline design properties and recommended welded steel pipeline thickness, material selection, joint welding types, and pressurized surge tanks, and combination air and vacuum relief valves installed on the transmission mains.

In 2010, a preliminary pressure surge analysis was completed for the proposed 50 MGD HBDP and associated water conveyance system. NHC constructed a hydraulic analysis model of the system and associated facilities using the TransAM software. The consultant had considered three scenarios which was performed at a preliminary planning stage.

Black & Veatch recommends performing a detailed surge analysis based upon the latest flow scenarios and pipeline arrangements and the model should be re-evaluated, checked and updated based upon booster pump station design selection and finalized conveyance piping mains and layout.

2.4 METHODS OF DEMAND AND POWER CONSUMPTION MANAGEMENT

The EOCF2, JTM, and ATM are currently operated under pressurized flow conditions controlled by the static head at the Diemer WTP. Pressure is controlled by pressure control facilities including the Santiago Creek P.C.S. and Coastal Junction P.C.S. Demand is currently managed by maintaining static head at the Diemer WTP and maintaining acceptable pressure at service connections along the alignment. The integration of the HBDP and groundwater pump back would change Metropolitan's current management procedure for meeting demands in its system. The addition of a steady base load from the HBDP will reduce the demand on the Diemer WTP and thus give Metropolitan less control over the system via gravity feed. There is also the opportunity to manage HBDP supply based on demand, but with an increased operating cost, if less than the full capacity of the plant is integrated. Early communication between Metropolitan, MWDOC, and Poseidon is necessary to determine a supply management strategy that will not adversely impact the system. A comparison between the current operating conditions in the EOCF2 and the proposed operating conditions of the Poseidon conveyance pipeline are presented in Table 2-1.

Table 2-1. Hydraulic Management System Comparison

PARAMETER	METROPOLITAN CENTRAL POOL DISTRIBUTION (INCLUDING EOCF2)	PROPOSED POSEIDON CONVEYANCE
Hydraulic Control Method	Pressurized Distribution System	Pumped
Description	Hydraulic grade of distribution system established by water surface elevations at water treatment plants at high grade	Pump station delivers water to conveyance system to desired pressure
Location	Robert B. Diemer WTP	HBDP/booster pump station
Major Pipeline Appurtenances	Pressure control facilities (P.C.F)	Booster pumps, surge tanks

PARAMETER	METROPOLITAN CENTRAL POOL DISTRIBUTION (INCLUDING EOCF2)	PROPOSED POSEIDON CONVEYANCE
Hydraulic Flow Control	Precise Flow Regulating Valves	HBDP Product Water Pump Station (Constant Speed or VFD Drive)

2.5 IMPACTS TO OTHER WATER SUPPLIES IN THE AREA

This section discusses the physical impacts of HBDP and groundwater pump back integration to groundwater, surface waters, and recycled water programs in the region. This section also provides recommendations for the steps necessary to address potential impacts.

2.5.1 Groundwater

Physical impacts of the integration of a groundwater pump back system and the HBDP to groundwater in the region are expected to impact groundwater in the OC basin to varying degrees based on demand and emergency conditions. The San Juan Basin is not expected to be substantially impacted by groundwater pump back and HBDP integration because only 5% of potable water in south county is supplied from groundwater and the other 95% of potable water is imported. The addition of HBDP water will realistically be used to offset imported water use from other sources.

The integration of the HBDP in the system has the potential to offset groundwater demand with desalinated water primarily in the OC basin. A portion of the 50 MGD supplied from the HBDP to the EOCF2 will supply consumers within the OC basin and could offset groundwater demand. The degree to which demand for groundwater could be offset is unknown. Said offset will be dependent on the manner in which HBDP is delivered to the system, market conditions, operational constraints, and agreements that MWDOC or OCWD reaches with member agencies in the region.

A groundwater pump back system could directly impact the OC Basin by extracting groundwater through supply wells in the southern portion of the OC basin. Demand from a new set of wells has the potential to decrease the local groundwater storage and, thus, increase the depth to groundwater in the region. However, the groundwater pump back system will only be used on an emergency basis and therefore is not expected to have a substantial physical impact on the OC Basin. The groundwater pump back wells will be limited to a maximum withdrawal of 6,000 acre-feet, which represents approximately 3.6% of the total OC Basin groundwater production in 2018. A well siting study is recommended by B&V to ensure that the wells are placed in locations that would have minimal impacts on the basin and surrounding wells.

Groundwater source quality will be an important consideration when siting the groundwater pump back wells. Groundwater contaminants that have recently received a lot of attention from the State Water Resources Control Board (SWRCB) are per- and polyfluoroalkyl substances (PFAS). PFAS is a category of synthetic organic compounds common in food packaging, commercial household products, and aviation that are known to cause adverse health outcomes for humans (USEPA, 2019). A recent SWRCB mandate ordered that 53 wells be monitored for PFAS in the OC Basin as part of a statewide PFAS investigation plan. OCWD has since committed to monitoring for PFAS throughout the OC basin and to shutdown wells with concentrations of total PFAS above the 70 ng/L CA DDW Interim Response Level. More permanent MCLs are expected to be put in place in the near future by the EPA and SWRCB.

With potential increased regulations on PFAS concentrations in drinking water from the EPA and SWRCB coming in the future, it will be important to site the groundwater pump back wells in a region that is either not contaminated with PFAS/other pollutants or to provide appropriate wellhead treatment to remove pollutants. Appropriate well field siting will reduce wellhead treatment requirements and potentially reduce monitoring costs.

The groundwater pump back wells also have the potential to impact the south basin contaminant plume located under a portion of Irvine, Tustin, and Santa Ana. The VOC-contaminated plume is roughly 2 square miles and has forced the shutdown of supply wells in the region. The implementation of the proposed wells near the existing plume could impact the migration of the plume and needs to be considered.

Black & Veatch recommends the development of a groundwater pump back well siting study to fully investigate the impacts of the addition of supply wells in the southern OC Basin. The well siting study shall take into account both groundwater availability and quality. Once water quality of the site is confirmed, wellhead treatment techniques will need to be determined. Part of the study shall also include a survey of permits necessary for the proposed well site. Consultation with OCWD will play an important role in the development of the well site(s) and determining allowable well supply rates.

2.5.2 Surface Water

For the purposes of this investigation into the physical impacts to surface waters in the region, surface water is defined as storage tanks, reservoirs (covered and uncovered), lakes, and rivers. System hydraulics downstream of the EOCF2 tie-in point with the HBDP, including storage tanks and top covered reservoirs, are expected to be maintained per their normal operating conditions. However, HBDP integration and groundwater pump back are expected to relieve the upstream Diemer WTP of demand. The 50 MGD supply from the HBDP will supply a baseload to the EOCF2 and will make the Diemer WTP demand decrease overall and fluctuate with seasonal demand of the system. The reduction in demand would reduce the Diemer WTP's overall take from the SWP or CRA. A reduction in take from either of these systems could result in elevated upstream reservoir levels.

The operational procedure of the Diemer WTP will need to be evaluated prior to integration to properly manage the system. Communication between Metropolitan and MWDOC will be important to understand anticipated impacts upstream of the HBDP tie-in.

2.5.3 Recycled Water

Physical impacts to recycled water programs in the region from the HBDP and groundwater pump back integration are not expected as the volume of wastewater entering recycled water programs is not anticipated to change as a result of integration. See Section 3.8 for anticipated impacts to recycled water programs as a result of water quality.

3.0 Water Quality Issues Related to Integration

Pertinent water quality issues associated with the integration of the HBDP and groundwater pump back systems are presented in this section. Included is both a discussion of issues specific to desalinated water and groundwater integration as well as recommendations for the next steps necessary to address water quality concerns addressed herein.

3.1 SYSTEM WATER QUALITY ISSUES OF BLENDING VARIOUS SOURCES

Blending of potable water sources with desalinated water is a common practice and is implemented around the world. Examples of large-scale desalination plants that currently blend with potable water sources via in-pipe blending and tank blending are presented in Tables 3-1 and Table 3-2, respectively.

Table 3-1. Examples of Large-Scale Desalination Plants Delivering Water via In-Pipe Blending

PLANT NAME	CAPACITY	LOCATION	ON-LINE DATE
Carlsbad Desalination Plant	50 MGD	Carlsbad, USA	2015
Gold Coast Desalination Plant	33 MGD	Tugun, AUS	2009
Sydney Desalination Plant	66 MGD	Sydney, AUS	2010
Ashkelon Desalination Plant	98 MGD	Ashkelon, ISR	2005
Valdelentisco Desalination Plant	36 MGD	Valdelentisco, SPN	2007

Table 3-2. Examples of Large-Scale Desalination Plants Delivering Water via Tank/Reservoir Blending

PLANT NAME	CAPACITY	LOCATION	ON-LINE DATE
Tampa Bay Seawater Desalination Plant	25 MGD	Tampa, USA	2003
Victorian Desalination Plant	108 MGD	Wonthaggi, AUS	2012
Perth Seawater Desalination Plant	33 MGD	Perth, AUS	2006
Tuas Desalination Plant	36 MGD	Tuas, SGP	2005
Barcelona Desalination Plant	50 MGD	Barcelona, SPN	2009

Both Table 3-1 and 3-2 highlight the idea that both in-pipe and tank/reservoir blending are viable options for large scale desalination integration. Limitations on blending strategy options often come from hydraulic control scenarios, available space, and regulatory requirements. Water quality goals can be met with either scenario. For majority of the plants listed in Tables 3-1 and 3-2, either a blending study or model played a substantial role in the effective planning and operation of the aforementioned desalination blending projects. Blending models and studies can identify key issues with a proposed blending strategy and offer potential ways to mitigate them in the project planning phase.

Major water quality concerns when blending multiple water sources include disinfection byproduct formation (DBP), corrosion, disinfection residual management, and nitrification. The degree to which these concerns become an issue is primarily dependent on the blending ratio of each water source. A summary of potential impacts for each blending scenario is presented herein. A comparison of key constituents of concern is presented in Table 3-3.

Table 3-3. Comparison of Metropolitan Diemer Water, HBDP Water, and the Groundwater Pump Back Supply

PARAMETER	AVERAGE REGIONAL GROUNDWATER[1]	DIEMER WTP[2]	HBDP (TSM)[3]	HBDP (CDP)[4]
Flow (mgd)	TBD	32*	50	50
Chloride (mg/L)	80	50 - 103	75	77
Sodium (mg/L)	63	51 - 103	60	52
Calcium (mg/l)	81	28 - 76	20	24
TDS (mg/l)	441	294 - 654	350	233
TOC (mg/l)	0.52	2.5	N/A	0.3
pH	8	8.1 - 8.4	7.0 – 8.0	8.5
Alkalinity, as $CaCO_3$ (mg/l)	176	61 - 120	N/A	60
Disinfection Method	Chloramines	Chloramines	Chloramines	Chloramines

**Represents average flowrate in EOCF2. Value will likely change with each blending scenario & demand.*

Source: 1. 2017 Regional Groundwater Annual Water Quality Report Averages
2. 2016/2017 Metropolitan Annual Water Quality Report Averages
3. Poseidon/OCWD June 2018 Term Sheet Agreement
4. 2017 Carlsbad Desalination Plant Consumer Confidence Report Averages

Impacts of blending that are common to each blending scenario are corrosion potential and nitrification. Corrosion potential of each blend is dependent on many variables but can be manageable if corrosion control parameters such as LSI are controlled adequately at both treatment facilities as discussed further in section 3.5. Nitrification is dependent on chloramine residuals and free ammonia concentrations. If chloramine residuals are managed adequately and the ratio of chlorine to ammonia is managed, nitrification can be controlled in the distribution system.

Scenario 1 – Diemer WTP and HBDP

Blending Diemer WTP and HBDP water would have both positive and negative impacts on water quality. Positive impacts include the likely reduction in organic DBPs due to the low concentration of DBP precursors such as Total Organic Carbon (TOC) in desalinated water and an average reduction in TDS concentrations in the system. A potential negative impact from blending would be the increased decay rate of chloramine residuals due to the reaction with elevated bromide from desalinated water. Note that the impacts of elevated bromide can be mitigated with a larger second pass RO system and/or residual boosting stations in the conveyance system. These mitigation techniques and their impact on residual decay are discussed further in section 3.3.

Chloramine residual decay does pose a potential risk to operations, however with proper management of residuals and possibly additional chemical facilities, adequate residual concentrations can be maintained throughout the distribution system.

Scenario 2 – Diemer WTP and Groundwater Supply

As in Scenario 1, this blending scenario could reduce organic DBP formation due to the naturally lower TOC concentrations in the local groundwater compared to Diemer WTP. TDS concentrations in the system are not expected to exceed existing average Diemer WTP TDS concentrations because groundwater TDS concentrations are well within the range of average Diemer WTP TDS concentrations . Residuals in the system can be maintained per their current concentrations with the addition of wellhead disinfection on the pump back wells, as groundwater bromide concentrations are not significant enough to cause a residual stability issue.

Scenario 3 – HBDP and Groundwater Supply

A blend exclusively between HBDP water and groundwater supply is expected to be uncommon but could occur during a Diemer WTP shutdown. Like Scenarios 1 and 2, this blend is also likely to experience lower DBP concentrations due to the low TOC concentrations in both sources. TDS concentrations for the blend of these two water sources is expected to be within the range of Diemer WTP. Chloramine residual decay rates are expected to increase for this water source like Scenario 1, due to increased concentrations of bromide in the system. While chloramine residual decay rates are expected to increase, residual concentrations can be controlled in the system with adequate disinfection management at the treatment facilities or through chloramine boosting in the system.

Scenario 4 – Diemer WTP, HBDP, and Groundwater Supply

Like Scenarios 1 and 3, DBP concentrations are expected to be reduced. Also, like Scenarios 1 and 3, chloramine residual decay rates are expected to increase. The impacts of chloramine residual decay and corrosion have the potential to impact the system but can both be managed with properly executed post-treatment techniques at the treatment facilities and/or chloramine boosting in the system. Chloramine residual decay is discussed further in Section 3.3.

3.2 REGULATORY IMPACTS AND CONTROL INCLUDING DBPS AND MCL COMPLIANCE

Drinking water constituent concentrations for all California public potable water producers are regulated by the US Environmental Protection Agency (EPA) and the California Department of Drinking Water (DDW). Both agencies regulate the MCLs of common constituents present in drinking water. The integration of both the proposed desalinated water and groundwater sources is not expected to exceed any MCLs regulated by the EPA or DDW.

3.2.1 Chloramine Disinfection

An important assumption made for this report is that all water sources are using the same secondary disinfectant. Blending water sources that have different secondary disinfectants has the potential to decrease residual concentrations and/or increase DBP formation. DBPs such as Total Trihalomethanes (TTHMs) and Haloacetic Acids (HAAs) are of particular concern when disinfecting with either free or combined chlorine. However, free chlorine tends to react quickly with organic carbon in treated water and forms TTHMs and HAAs more readily than chloramines. In order to avoid excess residual decay and additional DBP formation upon blending, it is recommended that all water sources utilize the same secondary disinfectant. Because the Diemer WTP uses chloramination, it is recommended that both the HBDP and the groundwater pump back wells use chloramination.

3.2.2 Impacts of Bromide

A specific concern for desalinated water is the formation of brominated DBPs during disinfection. Bromide ions present in desalinated water will react with free chlorine to form brominated DBP precursors, which have the potential to form brominated DBPs if organic DBP precursors are present. In a 2004 pilot study on potential DBP formation in a distribution system blended with desalinated water, conducted by Poseidon Resources and McGuire Environmental Consultants, it was concluded that blending desalinated water with surface and groundwater does not result in increased levels of TTHMs or HAAs (McGuire and Poseidon, 2004). In the study, desalinated water from a RO pilot plant (Br=0.73 mg/l) located at the Encina Power Plant in Carlsbad, CA was blended with three different source waters: Diemer WTP (Br=0.07 mg/l), IRWD chloraminated groundwater (Br=0.07 mg/l), and the City of Newport Beach chlorinated groundwater (Br=0.04 mg/l). These source waters are representative of the source waters for MWDOC and the proposed new local water supplies. Each water source was blended individually with disinfected desalinated water and final DBP concentrations were compared to a control of DBP concentrations in local sources alone. The final pilot study report concluded that TTHM and HAA concentrations in all blended sources were less than or equal to concentrations in the three existing sources waters and were well below the MCL. The lowered TTHM and HAA DBP concentrations in the blended samples are attributed to the lower DBP precursor concentrations natural to RO permeate (i.e., TOC), which causes a dilution of overall DBPs in blended waters.

The study did, however, find that DBPs concentrations did shift toward more brominated DBP species. TTHM species such as bromoform increased from 5 ppb in the Diemer control water to 16 ppb in the blended water. This increase in brominated DBP species was found to be due to higher concentrations of organic carbon in Diemer WTP water reacting with brominated DBP precursors present in disinfected desalinated water. Despite an overall increase in brominated DBPs, the overall concentration increase of these brominated species is considered marginal and both TTHM and HAA concentrations remained well below their respective MCLs.

A recent case study released by the Water Research Foundation on Carlsbad Desalinated Seawater Integration found that the integration of the Carlsbad Desalination Plant decreased THM and HAA DBP formation in the distribution system (Alspach & Imamura, 2018). The study noted that THM and HAA concentrations were maintained well below the MCL throughout the entirety of operation and that there was not a substantial increase in brominated DBPs.

Conclusions from the Poseidon pilot study and the WRF Carlsbad case study suggest that with the correct dosing of disinfectants and management of TOC, DBP formation is not expected to be an issue and DBP MCL limits are expected to be met. However, due to source water quality changes since the Poseidon pilot study and out of an abundance of caution, Metropolitan recommends a bench scale DBP formation study be conducted in order to determine DBP formation rates based on current water qualities of the three sources. While Black & Veatch believes such additional studies are not strictly necessary, they are inexpensive to implement and would provide reassurance to all stakeholders that DBP formation will not be problematic.

3.3 RESIDUAL DECAY, STABILITY IMPACTS, AND CONTROL, INCLUDING BIOLOGICAL AND BIOFILMS

This section discusses factors affecting residual decay rates and stability of the HBDP and groundwater pump back.

3.3.1 Residual Decay

Maintaining chloramine residuals in the system is the key consideration in limiting biological growth in the distribution system. If chloramine residual concentrations in the distribution system are not maintained, both nitrate and DBP formation become a concern. The most effective way to control residuals in the system is to ensure each water source has sufficient residual to last in the system based on decay rates and residence times.

The primary water quality parameters that impact chloramine decay rates are TOC, pH, and bromide (primarily related to desalination). TOC concentrations are known to react with all chlorine disinfection processes and reduce residuals in transmission systems. However, because desalinated water commonly has low TOC concentrations and local groundwater reports show TOC concentrations less than Diemer WTP, TOC is not expected to have an increased impact on residual decay. Maintaining pH values greater than 8 in a transmission system are generally expected to not impact residual decay. Because both the Diemer WTP and local groundwater pH levels are generally around 8, pH is also not expected to have a substantial impact on residual decay.

High concentrations of bromide are present in seawater and a percentage of the bromide concentration remains present through the desalination process and in RO permeate. Concentrations of bromide in desalinated water have been shown to increase the decay of chloramine residuals in treated water. Previous studies have shown that bromide concentrations less than 0.3 mg/L are required to reduce the impacts of bromide on residual decay (CH2M HILL, 2012)(Zhang et al., 2012).Options to remove excess bromide from RO permeate include adding additional second pass RO capacity. While this option is costly, it is the most effective way to reduce bromide concentration in desalinated water and reduce both residual decay and brominated DBP formation. For this this reason, Metropolitan recommends a maximum bromide concentration of 0.3 mg/L be set for the HBDP.

The impact of bromide that cannot be removed through RO processes is generally managed by dosing the system with enough disinfectant (free or combined chlorine) to maintain adequate residuals (generally 2-3 mg/L). This can be done by providing a larger dose at the treatment facility or by employing chloramine boosting stations in the system. The San Diego County Water Authority

(SDCWA) uses chloramine boosting stations to maintain residuals following the blend of Carlsbad Desalination Plant water and Twin Oaks Valley Treatment Plant water, for example.

Research has also shown that ample contact time in a contact basin can help reduce the impacts of monochloramine decay associated with bromide. In the West Basin Pipe Loop study, chloramine decay rates stabilized following the first 4 to 5 hours following disinfection (West Basin, 2014). This suggests that with a clearwell sized to accommodate 5 hours of detention time, chloramine decay can be managed, and adequate residuals can be achieved in distribution with disinfectant boosting following detention. Detention can also be accomplished in a transmission pipeline between the plant and tie-in to accomplish the desired detention time prior to a final boosting. Disinfectant stability and management are further discussed in sections 4.1.1.6 and 4.3.3 of Hazen's Desalination Integration White Paper.

Black & Veatch recommends that MWDOC develop the previously recommended blending study to also model water quality parameters. An early task will be to predict water age, residence times, and residual decay for a spectrum of operating scenarios. Modeling will support an assessment of needs for secondary disinfectant dosing and residual management, including potential need for additional secondary disinfection facilities to be located in the distribution system or the addition of a larger capacity second pass RO system. Black & Veatch also recommends a bench scale test be conducted to determine chloramine stability in the blended system. The bench test will help identify whether chloramine boosting will be needed and determine necessary dosages of secondary disinfectant required.

3.3.2 Impacts of Temperature

Higher temperatures in seawater result in increased RO membrane permeability. While increased permeability reduces pump energy requirements it also increases the salt flux across the RO membrane and results in increased effluent TDS concentrations. Seawater temperatures in the region typically range between the 50 and 75˚F with an average temperature of 62˚F over the last 20 years according to the Scripps Institute of Oceanography Newport Beach Temperature data history. An important aspect to note is that the HBDP design, as it stands today, will no longer use the existing AES power generation facilities condenser water effluent as its intake. Current intake plans involve the use of an intake pipeline directly from the ocean outside the plant. HBDP influent temperatures are expected to be roughly the same as ambient ocean temperatures as a result.

Increased temperatures are also a concern because they can increase the nitrification rate of ammonia. This primarily becomes a concern in the distribution system where there is excess ammonia, generally areas with long residence times and low disinfectant residuals. Nitrifying bacteria are most productive at a temperature between 77 to 86˚F (AWWA, 2013). In systems where temperature cannot be easily managed, increased residual dosing is often required.

Water quality impacts from temperature can be significant if not managed adequately. While many of the effects of increased temperatures can be managed operationally, temperature limitations are important to ensure predictable water quality. Final temperature limitations will need to be agreed upon in a future term sheet agreement between Metropolitan and Poseidon in order to address potential water quality issues.

3.4 LOW DEMANDS CREATING LONG RESIDENCE TIMES

Low demands in a system can create a variety of water quality problems associated with long residence times. DBP formation, residual decay, and nitrification are some of the primary concerns. DBP formation potential increases with water age, resulting in high DBP levels as water demands decrease. This can lead to DBP concentrations exceeding the MCL and posing a health risk to consumers. Low demands and high residence times can also pose a health risk by consuming disinfectant residuals in the system. A reduction in residual concentrations leaves potential for microbial growth in a system, a potential health risk for consumers. Accompanied by reduction in chloramine residuals is nitrification. As combined chlorine reacts in the system, ammonia is released and provides an electron source for nitrifying bacteria to convert free ammonia into nitrate. Nitrate concentrations are known to restrict oxygen transport in the bloodstream and is the cause of blue baby syndrome in infants.

A major factor in determining whether long residence times will be an issue is the tie in location of the HBDP and groundwater pump back. In order to prevent the potentially negative impacts of low demands, adequate residual management is required. As discussed in Section 3.3, a blending study is recommended in order to investigate where there is potential for long residence times and residual decay. A study of this kind will facilitate the determination of a combined chlorine dose for the HBDP as well as whether chloramine boosting is required.

3.5 CORROSION CONTROL

Corrosion control in the blended system will rely primarily on the post-treatment processes at the HBDP and Diemer WTP. Currently, there is no plan for extensive treatment at the groundwater pump back wells and the Diemer WTP is expected to maintain its current post-treatment methods as one of the largest treatment facilities in the region. This will require the majority of modifications for corrosion prevention to be orchestrated by the HBDP post-treatment system.

Primary concerns with corrosion are the leaching of materials into the water supply causing health risks for consumers and the degradation of conveyance infrastructure. Pipeline materials such as cement mortar linings, steel, iron, copper, and lead can be leached from the surface of pipes and can pose serious health risks. Degradation of pipes can lead to excessive pipe leaks and failures.

Corrosion is complex and can be measured with a variety of indices. Key considerations when addressing corrosive potential of water include pH, alkalinity, hardness, TDS, and temperature. These 5 parameters and the relationship between them is often expressed in indices that represent overall corrosion potential. Some of applicable indices to the source waters considered include Langelier Saturation Index (LSI), Calcium Carbonate Precipitation Potential (CCPP), Aggressive Index (AI), Larson Ratio (LR), and Chloride to Sulfate Mass Ratio (CSMR). These corrosion indices and their applications to this project are defined below:

Langelier Saturation Index (LSI)

LSI describes the corrosivity of water through a classification based on how close the overall water quality is to saturation of carbonate. The value is expressed in terms of pH and is generally considered corrosive if negative and scale-forming if positive. Maintaining a slightly positive LSI value (+0.1 - +0.5) in a blended system creates an environment where protective scale can form, and the scale will be protected from stripping.

Calcium Carbonate Precipitation Potential (CCPP)

CCCP is a measure of the concentration of calcium carbonate that will either precipitate or dissolve in a solution. It is generally desired to maintain a CCPP between +0 and +10 mg/L to minimize corrosion and excessive scaling.

Aggressive Index (AI)

AI indicates the corrosivity of water and is a function pH, calcium hardness, and total alkalinity. Generally, AI values >12.0 are considered non-corrosive.

Larson Ratio (LR)

LR is a measure of the corrosion potential of water and is a function of chloride, sulphate, and bicarbonate. LR has been commonly used to determine corrosion potential of water on iron pipes.

Chloride to Sulfate Mass Ratio (CSMR)

CSMR is simply the mass ratio of chloride to sulfate in water. Because sulfate concentrations are low in RO permeate compared to surface water, CSMR values in desalinated water are generally much higher than surface water. Previously conducted research has shown that waters with CSMR values greater than 0.5 and alkalinity less than 50 mg/l are a concern with respect to lead release in a distribution system (Nguyen et al., 2011). CSMR could pose a concern in distribution systems with high lead content in pipes if alkalinity levels are uncontrolled.

A previous corrosion study that focused on the impacts of integrating HBDP water with Diemer WTP water concluded that the blend would remain non-corrosive if the HBDP product water maintained the following product water quality performance (McGuire, 2002).

- pH: 8 to 8.5
- LSI: 0.0 to +0.5
- Alkalinity: >40 mg/L

This study, conducted by McGuire Environmental Consultants, was used as the basis for the Carlsbad Desalination Plant water quality specifications. However, while the study describes water quality that will remain non-corrosive in desalinated/surface water blends, it does not consider the addition of groundwater. While groundwater pump back is not expected to be a continual water source in the EOCF2, further consideration of varying source blending is recommended.

While each corrosion index listed previously in this section has different water quality parameters that impact their value, alkalinity is a common parameter that has an impact on each of those presented. With proper post-treatment techniques, appropriate alkalinity levels in the system can be maintained and all indices are expected to be met. Because LSI has been an effective index used at the CDP during operation and in the previous corrosion study, it is considered the most applicable index of corrosion for the HBDP.

Black & Veatch recommends that MWDOC update the previous corrosion study conducted by McGuire Environmental Consultants to reflect the most up-to-date water quality data, and to address the addition of groundwater into the system. Such a study would include a water quality model updated with recent water quality data from each anticipated water source and a determination of goal system water quality parameters in order to maintain a non-corrosive environment.

3.6 IMPACTS ON AGRICULTURE & HORTICULTURE

Irrigation water quality depends on a variety of factors and constituents. The primary constituents present in desalinated water that may have an impact on agriculture in the region are dissolved salts such as sodium, chloride, and boron. High dissolved solids concentrations in water can limit the ability for crops to absorb water from the soil due to higher osmotic pressures in the soil. Dissolved ions in irrigation water can also inhibit plant growth by altering soil structure. Irrigation waters with high ratios of sodium to the sum of calcium and magnesium will reduce soil permeability and water uptake by plants (USDA, 2011). The Sodium Adsorption Ratio (SAR) is a common measurement of water used to determine the degree to which sodium will be adsorbed by soil.

Boron is essential to plant health in low concentrations. However, high boron concentrations in irrigation water have been found to limit crop growth, decrease yields in certain crops, and cause aesthetic issues to a variety of plants (Nable, 1997). Boron toxicity occurs when boron builds up in the soil faster than it is utilized by the plant. Boron concentrations in desalinated water are naturally high compared to other source waters. Based on Poseidon's preliminary design, the planned average product water boron concentration is 0.75 mg/l, a concentration that can reduce crop yield in certain crops such as citrus and avocados (Grieve, 2012). However, this concentration would only be seen if there are areas that receive 100% desalinated water.

Planned water quality for the HBDP listed in the June 2018 OCWD terms sheet for TDS, SAR, chloride, sodium, and boron are presented in Table 3-4. Due to their relatively low concentrations in the planned desalinated water, TDS and SAR are expected to have a negligible impact on agriculture in the region. Previous reports studying the impacts of the HBDP water quality have also concluded that TDS, sodium, chloride, and SAR concentrations will have no significant impact on local horticulture (Trussell et al, 2016).

Table 3-4. 2018 Poseidon/OCWD Term Sheet Selected Water Quality Parameters for HBDP

QUALITY PARAMETER	MEAN	MAXIMUM
Total Dissolved Solids (mg/L)	350	500
Chloride (mg/L)	75	100
Sodium (mg/L)	60	80
SAR	5	6
Boron (mg/L)	0.75	1

Source: 2018 Poseidon/OCWD Term sheet

Concentrations of boron in desalinated water do, however, have the potential to impact certain crops known to be present in the region. Citrus, avocados, and certain berries are considered sensitive to boron and can be negatively impacted with boron concentrations between 0.5 mg/l – 0.75 mg/l, with some crops sensitive to concentrations <0.5 mg/l (Grieve, 2012).

Potentially impacted crops in OC, including citrus and avocados, were valued at over $10,000,000 in 2017 (OC Public Works, 2017). Although, boron concentrations are anticipated to be diluted when blended with Diemer WTP and groundwater, some agricultural areas could see 100% desalinated water (depending on the selected points of integration, operational plans, and seasonal demand variations) and be impacted by high boron concentrations.

Local horticulture could also be impacted through integration of desalinated water. Prior to the construction of the Carlsbad Desalination Plant, an extensive study was to determine impacts of boron and other constituents present in desalinated water on plants in Carlsbad, CA. This study investigated the impacts that desalinated water with varying boron and chloride concentrations would have on 200 species of plants. The study found that when exposed to desalinated water with 0.75 mg/l boron and 56 mg/l chloride, 172 of the 200 plants studied would maintain acceptable appearance (Matheny, 2005). Due to the complexity of boron toxicity and its variance across species, impacts to residential plants in the MWDOC service area may vary from that of the previous Carlsbad study.

While 100% desalinated water may impact agriculture & horticulture, blended water would likely have significantly less impact. Black & Veatch recommends a study be commissioned to determine the impacts of desalination integration and boron toxicity on local agriculture and horticulture. Such a study would first use the planned hydraulic model to predict what areas in the OC system would receive desalinated water, in what proportions, and when. This will enable MWDOC to identify specific areas to be studied further. A study would be similar in scope to that conducted for the Carlsbad project but would also investigate impacts to agriculture. This would include inventorying plant & crop species in identified areas receiving desalinated water, evaluating performance of identified plants & crops under expected boron concentrations, and determining the probable effects of irrigating with the new water source.

An option to control impacts of boron on agriculture and horticulture is to lower the HBDP allowable boron concentration to 0.5 mg/L. Lowering the HBDP effluent boron concentration would control boron at the source and reduce risk of negative impacts to local plant and crop life.

However, reducing the allowable effluent boron concentrations at the HBDP will likely require a larger second pass RO system and/or an increase in acid dose to remove a greater percentage of boron which may result in a higher unit cost for desalinated water. While this option may require a larger HBDP facility and result in increased cost, it would allow most plant life to be irrigated with desalinated water without negative impacts. Metropolitan recommends that the maximum boron effluent concentration be limited to 0.5 mg/L in order to protect local agriculture and horticulture.

3.7 IMPACTS ON GROUNDWATER

Potential routes for the HBDP water and emergency groundwater supply blend to enter the groundwater basins in the region are primarily through groundwater basin recharge programs, irrigation incidental recharge, and wastewater treatment plant effluent incidental recharge. Concentrations of constituents present in the blended water have the potential to enter the groundwater basin through these routes and change existing constituent concentrations in the basin. All water sources were considered and only HBDP water was determined to pose a potential for risk to allowable constituent concentration to groundwater basins in the MWDOC service area.

The groundwater basin plans for both the OC and San Juan Basins present groundwater quality objectives for key constituents that are of concern for each basin. Key constituents of concern that are present in the desalinated water and have constraints for each basin plan are TDS, chloride, and boron. A comparison of the Orange County Groundwater Basin Plan's water quality objectives and the planned HBDP water is presented in Table 3-5.

Table 3-5. Comparison of Orange County Groundwater Basin Plan Water Quality Objectives to Average HBDP Product Water Quality

PARAMETER	BASIN PLAN OBJECTIVE		POSEIDON/OCWD TERM SHEET
	San Juan Basin	OC Basin	
TDS (mg/L)	1200	580	350
Cl (mg/L)	400	250	75
B (mg/L)	0.75	0.75*	0.75
**Surface Water Basin Plan Objective*			

Per Table 3-5, TDS and chloride concentrations present in HBDP water are significantly less than both basin's objectives and are expected to reduce the overall TDS concentrations in the basins. Average concentrations of boron, however, are consistent with concentrations listed in both basin plans. While average concentrations of boron will not exceed the basin plan objectives, recharge of either basin with desalinated water could increase ambient boron concentrations in both aquifers over time due to the existing relatively low concentrations of boron in both aquifers. However, desalinated water is not expected to increase boron concentrations in either aquifer to levels that would impact either basin plan. Dilution of HBDP water with Diemer WTP and potentially groundwater will also decrease concentrations of boron for most customers and, thus, decrease the boron concentration entering each basin with respect to desalinated water. The impacts of desalinated water on the basin would be further reduced if the term sheet boron concentration is reduced from 0.75 mg/L to 0.5 mg/L as recommended by Metropolitan.

Another potential impact to local groundwater that requires consideration is the mobilization of metals within the aquifer due groundwater recharge. Previous studies, studying the impact of recycled water on groundwater recharge, have shown that recycled water filtered through reverse osmosis has the potential to mobilize metals within aquifers (Li et al., 2006). Arsenic has been identified as a metal with particular potential for desorption within the OC Basin. Data from OCWD's GWRS groundwater monitoring program has shown that there is a relationship between increased GWRS water concentration in the groundwater and increased observed arsenic concentrations at monitoring wells (2017 GWRS Annual Report). Findings from previous studies and data collected from the GWRS groundwater monitoring program suggest that arsenic leaching is primarily influenced by the ionic composition of recharge water (Fakhreddine et al., 2015) (Li et al., 2006). Specifically, increased divalent calcium & magnesium concentrations in recharge water limit arsenic desorption from soils. In the study conducted by Stanford University, it was determined that divalent magnesium had the greatest impact of the divalent ions on limiting arsenic desorption, due to the preferential adsorption of divalent magnesium to soil anions bonded to arsenic. An important finding from both studies is that TDS concentration (ionic strength) in recharge water has little impact on arsenic desorption in an aquifer. Instead, ionic composition is what limits desorption. High values of pH were also found to release arsenic in water, however, due to the high buffering capacity of soil sediments in groundwater, pH was determined to have no critical importance in arsenic desorption.

Based on findings from this research, arsenic desorption in an aquifer can be limited to concentrations well below the drinking water MCL by providing a sufficient addition of calcium and magnesium hardness in the post treatment of groundwater recharge source waters.

While there are routes through which either HBDP or groundwater pump back sources can enter the groundwater, it is not considered a significant source of groundwater recharge for the end uses found in MWDOC's service area. Black & Veatch believes that extensive groundwater recharge studies are not warranted for the HBDP as it is not anticipated to be significant recharge source as conceived in this paper. Black & Veatch suggests water quality parameters for the HBDP, hardness and alkalinity, be compared to the same parameters for existing sources supplying the MWDOC service area and that the HBDP be required to maintain those water quality parameters to provide similar hardness and alkalinity. A comparison of this kind will ensure that the groundwater in the region is not impacted negatively by integration.

If direct groundwater injection of HBDP water is considered in either basin, an additional study may be warranted to ensure that the results from the Stanford University experiment are applicable for a large-scale injection project.

3.8 IMPACTS ON RECYCLED WATER TREATMENT PLANTS

California wastewater reclamation projects are governed by the California Code of Regulations (CCR) Title 22 standards and regulations. Title 22 sets regulatory standards for all acceptable re-use applications as well as allowable treatment methods. Reuse water quality objectives for all major recycling facilities in the region require treatment facilities to treat to disinfected tertiary recycled water standards or higher. Title 22 standards generally focus on effluent water quality parameters such as turbidity and total coliform bacteria. More stringent regulations are often placed on recycled water discharges in areas with sensitive environments or specific water quality objectives. A comprehensive review of WDR and NPDES permits for recycled water users in the region identified key constituents that are regulated among the major recycled water producers: OCWD, IRWD, SOCWA, SMWD, ETWD, and MNWD. Key inorganic regulated constituents for each recycled water program are presented in Table 3-6.

Table 3-6. Recycled Water Effluent Quality Requirements for Major Regional Recycled Water Producers

PARAMETER	OCWD – GWRS	OCWD - GREEN ACRES PROJECT	IRWD	SOCWA/ SMWD/ MNWD	ETWD
Measurement method	Maximum Concentration Limit	12-month running average	12-month running average	12-month running average	12-month running average
TDS (ppm)	500	1050	910	910	910
Chloride (ppm)	55	N/A	375	375	N/A
Boron (ppm)	N/A	N/A	0.75	0.67	N/A

Source: RWQCB Waste Discharge Requirements & Master Reclamation Permits

HBDP and groundwater pump back water's average TDS concentrations are not expected to have any impact on recycled water treatment plants' ability to treat wastewater or meet their permit discharge requirements. Many recycled water plants that see greater percentages of HBDP water may actually see reductions in their recycled water TDS. Table 3-6 also shows the GWRS chloride concentration limit is below the average concentration of either desalinated or groundwater supplies; however, due to the advanced treatment RO facilities, no impact to GWRS is expected.

Of the constituents listed in Table 3-6, boron is the constituent that poses a significant impact to some recycled water producers in the region. SOCWA, MNWD, and SMWD recycled water treatment facilities' Waste Discharge Requirements permit (WDR) specifies that recycled water effluent from its facilities cannot exceed a 12-month average 0.67 mg/L boron concentration. If only desalinated water is considered, SOCWA's recycled water boron concentration limitations would be exceeded. Previous research has also shown that boron concentrations can increase as much as 0.25 mg/l during the transition from potable water to wastewater due to consumer waste (Malcolm Pirnie Inc, 2009). With additions from consumer waste, recycled water producers that receive 100% desalinated water could see average boron concentrations as high as 1.0 mg/l. However, it is important to note that a boron concentration of 0.75 mg/l in desalinated water represents a water quality that is only expected to occur due to high temperature events and aged RO membranes. The average product water boron concentrations of the Carlsbad Desalination Plant in 2017 was 0.59 mg/l, which is anticipated for the HB plant. However, even with HBDP normal operating conditions, water recycling facilities could see excessive boron concentrations due to the addition of incremental consumer waste.

Concentrations of boron entering each wastewater and water recycling facilities cannot be accurately predicted within the scope of this study. It is expected that boron concentrations will increase in some facilities that will be served by a portion of desalinated water, but the extent of the increase is unknown. Boron mitigation techniques including adding additional second pass RO capacity or increasing the second pass pH may need to be considered by Poseidon. In order to ensure that wastewater recycling facilities do not violate their permits, Black & Veatch recommends a study be conducted in order to determine maximum boron concentrations at wastewater recycling facilities. Such a study would include an analysis of the blending model previously recommended to determine the regions that will receive the greatest concentration of desalinated water. A mass balance would then be used to determine boron concentrations expected at regional recycling facilities and whether permit violations are expected.

3.9 IMPACTS ON NPDES PERMITS

National Pollutant Discharge Elimination System permits (NPDES) in California are regulated by the EPA and the State Water Resources Control Board (SWRCB) and are required for any entity that discharges a point source to water of the United States. NPDES permits issued to wastewater treatment facilities regulate constituents that have potential to negatively impact water bodies and other environmental factors. Common constituents such as Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS) are regulated for all wastewater treatment facility discharges. Discharge locations that are particularly sensitive may have more stringent regulations and more regulated constituents.

A review of all NPDES permits issued to wastewater treatment dischargers in the region identified key constituents that are regulated among the three major wastewater NPDES permit holders OCSD, IRWD, and SOCWA. Key inorganic regulated constituents in the region are TDS and boron. Of the major wastewater districts in the MWDOC service area, IRWD's NPDES permit has the most stringent/only regulations on inorganic constituents. IRWD's NPDES permit stipulates maximum 12-month running average concentrations of 720 mg/L TDS, 375 mg/L chloride, 0.75 mg/L boron. OCSD's and SOCWA's NPDES permits do not regulate any of these constituents.

Much like impacts to recycled water programs in the region, the effects of integrating groundwater and desalinated water into the system are not expected to have any negative impacts due to TDS or chloride concentrations as both sources have concentrations well below the NPDES permit regulation. Therefore integration of the HBDP or groundwater pump back will not cause a NPDES violation due to TDS or chloride. As discussed in Section 3.8, the concentration of boron in desalinated water will likely cause an increase in boron concentration in some wastewater treatment plant influents, including IRWD. Under HBDP/Diemer WTP blending conditions and Diemer WTP/groundwater, boron concentrations are not anticipated to violate NPDES permits in the region. However, if a WWTP were to receive wastewater supplied by 100% HBDP water, influent flows could contain boron concentration close to 1.0 mg/l during HBDP high temperature and/or aged membrane water quality events and with the addition of consumer waste. However, desalinated water will only be a part of the water supply portfolio in OC and for each member agency. The diversified portfolio of the region makes the chance of any single WWTP receiving wastewater supplied by 100% HBDP water highly unlikely.

As recommended in Section 3.8, Black & Veatch recommends a study be conducted in order to determine maximum boron concentrations at wastewater recycling facilities and non-recycling WWTPs. A study of this kind would determine if there is risk of NPDES permits being violated with the current water quality planned by Poseidon.

3.10 REVIEW OF WATER SYSTEM PIPELINE MATERIALS IN SOC

Both finished water quality and pipe material are important factors to consider during the planning and design phase. A review of the pipe materials of the major transmission mains likely to be directly affected by the HBDP and groundwater integration is presented in Table 3-7.

Table 3-7. Major Transmission Line Pipe Materials

PIPELINE	DIAMETER (IN)	MATERIAL
EOCF2	54" - 78"	Cement Mortar Lined Steel
JTM	60"	Prestressed Concrete
	45" - 60"	Cement Mortar Lined Steel
	45"	Concrete Cylinder
	36"	Ductile Iron
ATM	24" -42"	Asbestos Cement
Irvine Cross Feeder	42"	Prestressed Concrete

Corrosion potential for each of the pipe materials listed in Table 3-7 is dependent on finished water quality of the blended product water. Managing post treatment techniques at the HBDP will be the most effective way to prevent corrosion of the network pipe materials.

Pipes with cementitious linings have been shown to be vulnerable to leaching in desalinated waters that have not been re-mineralized. However, under re-mineralized conditions the impacts to cementitious pipe linings have been shown to be minimal (Trussell et al., 2016). A key measurement in determining susceptibility of a cementitious lining to a source water is the calcium carbonate saturation, measured as LSI. A product water with an LSI above 0 will protect cement lined pipes from excess leaching. It is recommended to maintain an LSI between 0 to 0.5 in the blended water in order to protect cement lined pipes without creating an oversaturation of calcium carbonate.

Unlined ductile or cast-iron pipes in the system do have potential to be adversely impacted through the introduction of the two new water sources. Unlined iron pipes introduced to new water sources have been known to create “red water” events. Red water events are understood to occur due to the leaching of iron from iron-based pipes in a distribution system. Like the management strategy for cement lined pipes, maintaining calcium carbonate saturation in the blended product water protects unlined iron pipes from excessive leaching. However, even with attempts to match water quality, blending a new water source into an existing system with unlined iron pipes can cause red water events for a period following introduction of a new source (Trussell et al., 2016). Service connections within local water districts may have unlined iron pipes that could lead to a red water event upon first integration of the new water sources.

Lead and copper pipes and fixtures with high lead content, historically common in household plumbing, have been reduced significantly since laws have regulated them. However, there are some pipes and fixtures remaining in use in the system. Pipe loop studies evaluating the effect of desalinated waters on lead and copper pipes concluded that integration of desalinated water into a system will not violate the Lead/Copper Rule requirements with proper post-treatment (West Basin 2014; Loveland et al., 2010). Lead and iron releases are not expected to be an issue with integration of either HBDP water or groundwater. However, due to the 2007 revision in the US EPA Lead/Copper Rule, state approval will be required in order to introduce a new water source into a drinking water system. This process may require temporary additional monitoring by agencies throughout the county to ensure compliance.

Upon review of the pipeline materials in the MWDOC service area, specifically south OC, long-term impacts to pipeline materials and water quality from the integration of HBDP water and/or local groundwater are expected to be manageable with adequate post treatment of finished water. Short term impacts of integration, however, have potential to occur even with common post-treatment techniques. Releases of iron (red water) during a short-term period following integration may occur in areas with unlined iron pipes. As discussed in Section 1.4, Black and Veatch recommends a survey be conducted of local unlined iron water infrastructure in the MWDOC service area to make a determination as to whether a red water event may have a significant impact on the public. This survey would be conducted following the identification of areas that will receive the most prominent change in water quality in the previously recommended blending study.

3.11 NEED FOR PIPE LOOP STUDIES VS DEPENDENCE ON REVIEW OF PUBLISHED MATERIALS

Pipe loop studies are conducted to determine the impacts that a specified water quality has on varying pipe materials as well the changes in water quality following transmission. Results from a pipe loop study can help determine adequate pipe materials for a specific water quality or can alternatively identify water quality requirements for a specific system. Pipe loop studies are beneficial when adding a new water source to a system or blending two existing sources for the first time. However, a new pipe loop study is not necessary if previous studies have been conducted for a similar water quality and/or pipe material.

Multiple pipe loop studies have been conducted investigating the impacts of groundwater, surface water, and desalinated water on pipe materials. Four pipe loop studies of specific significance to this project are the West Basin Municipal Water District Ocean Water Desalination Water Quality Integration Study (West Basin Study), the WRF Seawater Desalination Implications for Drinking Water Quality Report (WRF Study), Long Beach Desalination Pilot Study (LB Study), and a Carlsbad corrosion pipe loop study (Carlsbad Study). In the west basin, WRF, and LB studies 100% desalinated water and various mixtures of desalinated/other potable water supplies were run through pipe loops of different material (West Basin, 2014; Loveland et al., 2010; Cheng et al., 2011). In the Carlsbad study post treated RO permeate and Metropolitan water were run separately through identical pipe loops of various materials (Blute et al., 2008). The West Basin Study's pipe loops consisted of cement mortar lined steel, unlined cast iron, and copper pipes. The WRF Study pipe loops contained brass faucets containing lead, galvanized iron, and soft copper piping. The LB Study's pipe loops consisted of unlined cast iron, cement lined iron and steel, and copper pipes. The Carlsbad Study's pipe loops consisted of new copper pipe, brass water service meters, new cement mortar lined steel pipe, and cast-iron gate valves.

All studies found that there were no significant impacts to pipe materials or water quality from integrating desalinated water into a potable water system with sufficient post treatment. Results from the aforementioned studies can be applied to this report due to the similarities in water quality and test pipe materials to those in the proposed system.

Review of existing published materials on pipe loop studies and introduction of new water sources on various pipe materials suggest the proposed integration will have negligible long-term impacts with proper post treatment of desalinated water, such that further pipe loop studies do not appear to be warranted. Metropolitan recommends however, that pipe loop studies be conducted using various pipe materials harvested from areas within the distribution system in order to obtain data specific to these proposed source waters. To cost effectively implement these pipe loop studies, Black & Veatch suggests that product water from the Carlsbad Desalination Plant be used as a proxy for HBDP, as the process design and product water quality are expected to be sufficiently similar for this purpose.

3.12 POTENTIAL AFFECTED AGENCIES

There are a number of variables which influence the likelihood that an agency in Orange County will be affected by implementation of proposed new water supply integration projects. These variables include:

- Where an agency receives water from the imported water system
- Where an agency receives current local water supplies
- How existing source water is conveyed to agencies
- Which of the supply projects in this report are completed and move into operation

Virtually all retail water agencies or wastewater/recycling agencies in the County could be impacted by water supply or water emergency projects along the way. That is why MWDOC contracted to have this work completed.

4.0 Summary of Regulatory Setting and Impacts

The purpose of this section is to describe agency coordination activities associated with integrating new water supply into the EOCF2 and ground water from the OCWD groundwater basin for future water supplies. The integration of new water supplies will include conveyance and pumping facilities which will require permitting approval by a number of federal, state, regional, and local agencies. The scope of this white paper is focused on the following jurisdictions as listed in Table 4-1 below.

Table 4-1. Summary of Regulatory Agencies Potentially Impacting the Project

AGENCY	REGULATIONS	DOCUMENTS
State Lands Commission	Govern state owned lands and cultural resources	Not anticipated for product water conveyance As required for Huntington Beach Intake and Outfall Existing System (AES Owned)
Regional Water Quality Control Board	NPDES Permits MS-4 Permits	Storm Water Pollution Prevention Plan General Construction Activity Storm Water Permit Critical Control Point (CCP) Monitoring Plan
DDW	Drinking water treatment facilities	Wholesale Domestic Water Supply Permit
Coastal Commission	Development impacting the ocean and coastal regions	Not anticipated for product water conveyance system facilities
AQMD	State and Federal Clean Air Regulations California Environmental Quality Act (CEQA)	Application for Permit to Construct and Permit to Operate
Local Jurisdiction	City of Huntington Beach, City of Costa Mesa, other Cities Building and Safety, Fire Protection, Regional Planning	Building & Safety Plan Check Public Works / Engineering Plan Check As Required
Direct Potable Reuse	Not developed at the State / Federal Level	Expert panel review of technical approaches underway

4.1 STATE LANDS

The California State Lands Commission is responsible for protection of natural and cultural resources. Projects that may involve new construction, reconstruction or improvement modifications that impact surface & submerged lands (California tidelands and submerged coastal seawater lands) should coordinate and submit application with the State Lands, Land Management Division for guidelines and laws, and regulations that are applicable.

It is our understanding that scope of the product water conveyance facilities for the HBDP and groundwater integration are not expected to directly impact lands governed by State Lands Commission. The involvement of State Lands may only be in regard to oversight. Contact and agency coordination should be initiated with State Lands' representatives during future project phases to ensure compliance with all future laws and regulations.

4.2 REGIONAL BOARD

Similar to State Lands coordination, the AES Facility NPDES permit would need to be updated per rules established by the Regional Water Quality Control Board. Other aspects of the new water supply discussions could include a survey of other potentially impacted NPDES permits because of the new water supply.

In regards to the HBDP conveyance system, emergency or off-specification water condition planning measures could be envisioned (i.e., emergency turnouts). Water conveyance to Santa Ana River (SAR), other OC rivers, bays, or storm drain facilities would require close coordination with NDPES Regional Boards. For example, under the City of San Diego's Pure Water Project, planning measures included development of options for disposing or reusing of off-spec purified water within the conveyance pipeline main in the emergency event of AWTF failure. The California Regional Water Quality Control Board, San Diego Region and City of San Diego created a Critical Control Point (CCP) Monitoring Plan to collaborate on identifying issues. The Plan discussed potential AWTF failures that resulted in water reaching the conveyance mains, potential diversion strategies that could be implemented, and facilities that were required to implement the diversions strategies. A similar CCP Monitoring Plan should be developed for the new water supply for EOCF2 for discussion between MWDOC and the OC Regional Board.

Under the new emergency OC Groundwater Well Project, Regional Board collaboration and involvement is also required during multiple stages of the Project including design phase, well drilling and development, and start-up. In general, any well water which is required to be discharged to nearby storm drains or streets is required to be coordinated with the Regional Board.

During the well drilling development stage, well construction activities require the Contractor to secure a temporary discharge application for well development and drilling fluids required to drill the well and install the well casing. The design of the well facilities will likely include blow-off piping, design of drain pipe to be routed to nearby street, storm drain system, or available sewer collection systems. The well production startup phase will require collaboration with the Regional Board to determine the duration of the startup and standard discharge protocol. Potable water wells will then be turned over to the local Water District for use. The new wells operations plan should be in accordance with the Regional Board guidelines and the local water district's general NDPES permit. The specific terms under which the water can be released during rare events (annual testing) would be included by the operation plan of the local Water District.

In addition, the existing OC reclamation facilities, wastewater plants (NDPES permit) and discharge constituents could also be impacted by new water supply water quality (i.e., impact to the basin plan objectives). A focus on Basin Plan Objectives and impacts related to key constituents such as boron, TDS, bromide, and DBPs should be discussed.

4.3 COASTAL COMMISSION

The HBDP Planning and Design had required close coordination with California Coastal Commission (CCC) which was highly involved with certain aspects of the plant design guidelines in terms of the intake and outfall facilities which also included the examination and the feasibility of subsurface intakes. In terms of the new water supply to the EOCF2, the result of the Commission (intake and outfall facility selected design) would likely impact the overall reliability and operability of the desalination plant and in turn impact the source water supply reliability.

4.4 CA DDW

The Department of Health Services (DHS) has provided Conditional Conceptual Approval of the HBDP. The DHS granted conditional approval based on the current HBDP treatment process to deliver potable water to water suppliers in the area. When in operation, DDW will require the HBDP to conduct monthly testing at the treatment facility and in the system that may impact MWDOC. DDW will also require permitting for developed wells in the groundwater pump back system. The groundwater pump back wells will need to receive approval prior to integration into the system and will also be subject to monthly water quality tests in accordance with DDW regulations.

4.5 AQMD

Air quality permitting should be performed by an environmental subconsultant in accordance with South Coast Air Quality Management District (SCAQMD) requirements. It is anticipated that an application for permit to construct and permit to operate is required for all project construction activities and facilities that may require emissions to the environment.

SCAQMD was created by state law as an agency responsible for the management of the air quality in Los Angeles, Orange, and Riverside Counties and the non-desert portion of San Bernardino County. SCAQMD promulgates rules and regulations applicable to all stationary sources of air pollution. SCAQMD issues a combined Permit to Construct / Permit to Operate for new equipment.

SCAQMD has formalized the environmental review process by developing Form 400-CEQA, which will determine if the project is exempt from CEQA or if an analysis of potential environmental impacts is necessary. If CEQA is necessary, the SCAQMD will contact the project applicant to discuss and assist with the steps necessary to fulfill the requirements of CEQA. The Agency is exempt from this permit if a CEQA and/or NEPA document was previously or currently prepared that specifically evaluates this project.

4.6 LOCAL JURISDICTION

Coordination with the local jurisdictions including the County of Orange and the City of Huntington Beach, Costa Mesa, and Newport Beach will proceed at the direction of MWDOC, as will contact with local groups and interests (e.g., developers, bike trail groups, etc.). Local agency coordination should be made with other utility jurisdictions to develop a clear plan for obtaining key record drawings and available GIS data to collaborate on the decision-making process related to the building of new infrastructure to support the new water supply integration. One illustration of this is understanding all buried infrastructure and identification of buried assets along proposed pipeline corridors.

4.7 DIRECT POTABLE REUSE

HBDP and groundwater pump back integration are not expected to impact potential future direct potable reuse projects (DPR). For purposes of this white paper, the water quality constituents present in influent flows to potential future DPR facilities are not expected to impact the design or operation of these facilities. In California, the overall framework and governing parameters are being developed and DPR regulations are not completely defined.

5.0 Approaches for Addressing Outstanding Questions

A summary of recommendations previously addressed in this report as well as a budgetary cost estimate for each recommendation are presented in this section. The budgetary cost estimates are general rules of thumb/professional advice to provide the reader with an idea of the potential costs involved. Not all of the testing delineated will be necessary for all projects and specific cost proposals will have to be worked out as specific project work is authorized. The budgetary cost estimates presented herein are estimates of generalized cost activities; these recommendations form a starting point for continued discussions on the appropriate timing, strategy, and responsibility among project proponents and others for bringing such supply projects to fruition. Responsibility and cost allocation have not been defined for such costs as that would need to be worked out on a project by project basis.

5.1 SCOPE

Below is a summary of recommendations proposed by Black & Veatch in this report.

1. Develop detailed operational scenarios for proposed new supplies
    a. Operation of proposed new supply facilities, capacity/production. Identify ways to ensure HBDP plant reliability. Determine HACCP methodology.
    b. Pumping and flow control into regional distribution system
    c. Adjustment of operation at Diemer/Metropolitan
    d. Service connections
    e. Pressure Control Structures

2. Develop groundwater pump back well siting study
    a. Determine favorable well locations for yield, water quality, and proximity to EOCF2 tie-in location

3. Develop hydraulic model of OC distribution system.
    a. Building on prior developed concepts, assess where new water supplies will go in system, including seasonal variation.
    b. Identify how water supplies will vary seasonally – 100% Metropolitan, 100% HBDP or groundwater pump back, blended supply. Address diurnal flow variations in hydraulic model.
    c. Identify areas where flow directions will reverse.
    d. Identify which service connections will be impacted and determine hydraulic detention time at interfaces.

4. Prepare a conceptual design report for the proposed integration options, inclusive of operational scenarios
    a. Define new infrastructure and modifications to existing infrastructure needed to accommodate the proposed operation.
    b. Detailed hydraulic and structural analysis, especially for existing infrastructure.
    c. Identify needed modification/upgrades needed to existing infrastructure.
        i. Pipeline structural integrity
        ii. Linings and coatings

        iii. Surge and pressure control facilities
        iv. Air and vacuum management
        v. Pressure control structures
        vi. Service connections
        vii. Identify need for chlorine booster stations in Central Pool areas.

5. Perform bench scale testing to determine disinfection residual decay rates and DBP formation.

6. Application of hydraulic model
    a. Perform water age/disinfection residual study for various operational scenarios. Determine strategy and/or facility needs to maintain residual.
    b. Identify areas of concern for reverse flow. Develop strategy for avoiding or managing potential impacts (pre-clean pipes that have never had reverse flow, line flushing, start-up/operational strategies, etc.). Define facilities needed to allow for such operations.
    c. Identify areas of concern for potential interactions of new supply with existing pipe materials (iron pipe with desal water, for example). Define extent of concern, develop strategy to manage issue or improvements needed to address issue.
    d. Utilize model and supporting analyses to predict water quality changes at downstream wastewater treatment plants and recycling facilities, inclusive of boron. If warranted, evaluate processes at said treatment plants to determine if water quality changes in influent would adversely affect plant performance or regulatory (NPDES, WDR, etc.) compliance. Identify treatment or other operational strategies to mitigate concern. (modify term sheet with Poseidon for product water quality, for example).
    e. Evaluate the locations where water quality may impact agriculture or horticulture. Assess impacts on crops and landscaping of different water quality constituents. Identify treatment or other operational strategies to mitigate concern.
7. Conduct pipe loop studies using pipe harvested from potential problem areas.

5.2 SUMMARY OF SCOPE, OUTCOMES, AND BUDGETARY COST

SCOPE	EXPECTED OUTCOME	BUDGETARY COST
1. Operational Scenario Study	**• Identify ways to ensure HBDP reliability** **• Determine HACCP methodology** **• Define operation of proposed facilities** **• Identify facilities needed to manage flows, pressures, system control.** **• Determine impact on operation of existing facilities (i.e. Diemer)** **• Determine impact on Member Agency operations** **Inform detailed hydraulic modeling analyses**	**$450k - $550k (more if more than 1 or 2 scenarios)**

SCOPE	EXPECTED OUTCOME	BUDGETARY COST
2. Groundwater Pump Back Well Siting	• Identify preferred locations for new wells	$100k - $200k (assumes groundwater/hydrogeology analyses provided by OCWD)
3. Base Hydraulic Model	• Determine flow routing, seasonal & diurnal variations • Identify system pressures • Predict water age • Identify areas experiencing flow reversal • Identify service connections impacted and HDT at interfaces	$325k - $450k (includes assessment phase already underway) (assumes development of model for a single scenario. Costs for modeling of additional scenarios included under #6)
4. Conceptual Design Report	• Define new facilities needed for supply integration • Identify modification to existing facilities needed to accommodate new supplies, proposed operations, management of water quality • Define cost of facilities • Provide basis of final design	$350k - $450k (conceptual report only) $1.5M - $2.5M (pre-design report)
5. Bench Scale Testing	• Determine disinfection residual decay rates to inform modeling evaluation, determination of disinfection management facility needs. • Determine DBP formation of blended water to ensure regulatory compliance	$50k - $100k
6. Hydraulic Modeling Based Analyses		
6A. Water Age	• Predict locations of concern for disinfection residual decay • Locate disinfection management facilities • Assess concentrations of other constituents	• Depends on number of scenarios required • Assume $75k - $100k per scenario for modeling • Assume $50k - $75k per scenario conceptually define and locate disinfection management facilities
6B. Reverse Flow	• Identify locations expected to experience reverse flow • Develop strategy to address concerns for areas expected to experience reverse flow	• Depends on number of scenarios required • Assume modeling cost included in Water Age analyses

SCOPE	EXPECTED OUTCOME	BUDGETARY COST
		• **Assume $50k - $100k to develop mitigation strategy**
6C. Piping/Water Interaction	• **Predict locations in OC where new water supplies will interact with pipe materials of concern**	• **Requires extension of model to include Member Agency/OC Customers systems** • **TBD pending OC Distribution System Model Phase 1 assessment**
6D. Assess Impacts on wastewater and water recycling facilities	• **Predict locations in sewersheds that will be supplied with new water supplies** • **Determine if change in constituent loading from new water supply has adverse effect on facility operation and regulatory compliance**	• **Depends on number of wastewater/recycled facilities impacted** • **Assume $300k - $400k per plant**
6E. Agricultural/Horticultural Impacts	• **Predict locations in OC where new water supplies would impact agriculture/horticulture** • **Identify strategies to mitigate areas of concern**	• **Requires extension of model to include Member Agency/OC Customers systems** • **TBD pending OC Distribution System Model Phase 1 assessment**
7. Pipe Loop Study	• **Conduct pipe loop studies using pipe harvested from potential problem areas**	• **$250k-500k**

References

Alspach, Brent and Imamura, Greg. Carlsbad Desalinated Seawater Integration Study. Water Research Foundation. 2018.

AWWA, 2013. Nitrification Prevention and Control in Drinking Water. Manual M56, 2nd Ed.

Blute, N.K., et al. "Integration of Desalinated Seawater into a Distribution System". Journal of the American Water Works Association, 100(9), 117.

Cheng, C., et al. "Applying LBWD's Pipe Loop Test Results for the integration of Desalinated Water". Membrane Technology Conference. PowerPoint Presentation.

CH2M HILL. A Literature Review and Bench Scale Study to Evaluate Chloramine Stability, DBP Formation and Nitrification Potential in Distribution System Carrying Blended Stream of Desalinated Seawater and Treated Surface Waters. September 2012.

Fakhreddine, et al. 2015. "Geochemical Triggers of Arsenic Mobilization during Managed Aquifer Recharge". Environmental Science & Technology, 2015, 49 (13), 7802-7809. June, 2015.

Grieve, Catherine M, et al. Plant Salt Tolerance ASCE Manual and Reports on Engineering Practice No. 71 Agricultural Salinity Assessment and Management (2nd Edition). Chapter 13 pp:405-459. 2012.

Hazen and Sawyer. White Paper – Integration of Doheny Desalinated Water with MET Water, other Desalinated Supplies, and Local Groundwater. April 2019.

Li, Quinlin, Mason Tomson, and Philip Bedient. 2006. "Leaching of Metals from Aquifer Soils during Infiltration of Low-Ionic Strength Reclaimed Water, Determination of Kinetics and Potential Mitigation Strategies", WateReuse Foundation Project Number WRF-06-005.

Loveland, J., Means, E, Amy, G., Reiss, C. 2010 Seawater desalination Implications for Drinking water Quality. Water Research Foundation.

Malcolm Pirnie, Inc. Huntington Beach Seawater Desalination Facility – Distribution System Water Quality Model. Prepared for Poseidon Resources. December 2009.

Matheny, Nelda. Evaluation of Proposed Irrigation Water Quality on Carlsbad Landscapes. HortScience Inc. Prepared for Poseidon Resources. December 2005.

McGuire Environmental Consultants and Poseidon Resources. Disinfection byproduct formation in a simulated distribution system: Blending Desalinated Seawater from The Poseidon Resources Corporation Pilot Facility with Local Drinking Water Sources. Prepared for Poseidon Resources. March 2004.

McGuire Environmental Consultants. Distribution System Corrosion Control for Desalinated Seawater. Prepared for Poseidon Resources. September 2002.

McGuire, M.J., E.G. Means III and J.P. Loveland, and J.Garvey. 2007. Use of Flavour Profile and Consumer Panels to Determine Differences Between Local Water Supplies and Desalinated Seawater. Water Science & Technology, 55(5):275-282.

Nable, Ross, et al. "Boron Toxicity". *Plant and Soil, 181-198*. 1997

Nguyen, Caroline, et al. Impacts of Chloride: Sulfate Mass Ratio (CSMR) Changes on Lead Leaching in Potable Water. Water Research Foundation. 2011.

Orange County Public Works. 2017 Orange County Annual Crop report. Orange County, CA. 2017.

Trussel, Rhodes, et al. Review of Proposed Water Quality Requirements for the Huntington Beach Desalter. Trussel Technologies, Inc. Prepared for Orange County water District.13 April 2016.

United States Department of Agriculture. Assessing Water Quality for Human Consumption, Agriculture, and Aquatic Life Uses. June 2011. Environmental Technical note No. MT-1 (Rev. 2).

US Environmental Protection Agency. “PFOA, PFOS and Other PFASs”. https://www.epa.gov/pfas/basic- information-pfas. 18 April 2019.

West Basin Municipal Water District, 2014. “Ocean water Desalination Water Quality Integration Study”. Final Report. June 2014.

Zhang, Y., Tseng, T.J., Andrews-Tate, C., Cheng, R.C., and Wattier, K. 2012. Pilot-scale evaluation of blending desalinated seawater into a distribution system. Journal of the American Water Works Association 104:7:43.

Hazen
Scott Foster Engineering, Inc.

MWDOC

White Paper – Integration of Doheny Desalinated Water with MET Water, other Desalinated Supplies, and Local Groundwater

Hazen No. 20121-000
July 2019

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AOB – Ammonia oxidizing bacteria

ATM – Aufdenkamp Transmission Main

AFY – acre-feet per year

CCPP – Calcium Carbonate Precipitation Potential

CFS – cubic-feet per second

CR – Lead and Copper Rule

DBP – Disinfection By-products

DDW – Division of Drinking Water

DPR – Direct Potable Reuse

EOCF#2 – East Orange County Feeder #2

HGL – Hydraulic Grade Line

JTM – Joint Transmission Main

LSI – Langelier Saturation Index

MET – Metropolitan Water District

MGD – million gallons per day

MWDOC – Municipal Water District of Southern California

NOB – Nitrate oxidizing bacteria

OCCT – Optimal Corrosion Control Treatment

RO – Reverse Osmosis

SCWD – South Coast Water District

SCP – South County Pipeline

SOC – South Orange County

TCPRS – Tri-Cities Pressure Reducing Structure

TDS – Total dissolved solids

UDF – Unidirectional flushing

WIP – Water Importation Pipeline

Executive Summary

This paper focuses on the **integration of desalinated water from the Doheny Desalination Plant into the South Orange County (SOC) region**. Black and Veatch is preparing a similar analysis for the Huntington Beach Desalination Plant.

The currently proposed Doheny Desalination Plant will produce an initial capacity of 5 million gallons per day (MGD) and potential ultimate capacity of 15 MGD of a high-quality, locally-controlled, drought-proof potable water supply. This is equivalent to an annual production of 5,321 acre-feet per year (AFY) initial and 15,963 AFY ultimate (as noted in SCWD's Draft Environmental Impact Report, assuming approximately 5% downtime). The supply can potentially function as a continuous base-load supply into the SOC region replacing a portion of the current demand on imported supplies, and/or as an emergency backup water supply should a disruption of imported supplies to the area occur.

This document provides a review of available information, studies, engineering reports, and agency coordination to summarize and identify the recommended steps/approach to resolve key outstanding integration issues, including issues such as:

- ***Changes in Regional Operation with the Introduction of Doheny:*** The introduction of Doheny to the system provides a new source of supply at the southern end of the system which has historically been supplied from the northern end of the system by imported water from MET. Operational impacts to MET upstream of the SOC region will likely be minor and may include operational impacts at the Diemer plant due to demand reduction and potential water quality impacts at mixing points of different water sources.
- ***Plant Operating Scenarios:*** Evaluating preferred operational scenarios based upon economic, operational, and reliability criteria. Scenarios may include operations as a base load water production facility, in continuous operation, intermittent operation to mitigate a shortfall in imported supplies (on a seasonal basis during regular dry periods or during drought periods), operation on and off line frequently to match preferred diurnal power tariff periods, and consideration of cost/benefit of operating scenarios versus utilization of imported supply and mitigation of potential impacts at MET's Diemer plant.
- ***Operational Reliability:*** Ensuring optimum system operation and integrity, by employing the Hazard Analysis and Critical Control Point (HACCP) methodology, and integrating effective communication at the operator interface.
- ***Hydraulic Design and Management:*** A comprehensive hydraulic model of the system is recommended, providing data on anticipated changes in HGLs in the system, flow reversal patterns, high/low velocities, stagnation and water age, and the effects of transients and pressure surges. These data will provide the framework for design of hydraulic control facilities (pumping facilities, storage, and turnout modifications), pipeline rehabilitation/ replacement requirements (due to age, materials, pressure class incompatibility, etc.),

development of a transient management strategy, and design integration with MET facilities to address MET's operational concerns.

- ***Corrosion Potential and Water Stabilization:*** Interactions between distribution system materials and the water being transported through the system can influence corrosion of distribution system materials and changes in the microbiological environment. The introduction of desalinated water into the SOC system requires an analysis of the interactions between different distribution system materials and the chemistry of delivered water, including the establishment of water quality targets and corrosion potential, strategies to minimize potential negative impacts of desalinated water, and testing approaches to develop system design and operational protocol.
- ***Avoidance of Impacts to End-Use Plumbing:*** Tying into the previous item on corrosion potential, consideration is needed for end-use plumbing in customers' homes and businesses. Lead, copper, and iron-based materials may be present and the corrosion strategy should consider end-use plumbing in addition to distribution system piping.

The document concludes with a listing of recommended studies to understand/address these issues and support further project development, including:

Issue	Recommended Study	Outcomes
Demand reduction at Diemer	Asset stranding optimization study	Recommended operating strategies at Diemer to minimize impacts to existing facilities. Consideration of implementation of both Huntington Beach and Doheny should be evaluated.
Overall Operational Strategy	Cost/benefit analysis (Diemer production versus Desal water)	Develop strategy to balance production from Doheny and imported water. Strategies should consider implementation of both Huntington Beach and Doheny. Identify facility requirements.
Low Demand Periods	Economic/Operational Analysis	Evaluate preferred method of operating the Doheny and Huntington Beach plants during low demand periods (cycling trains, idling trains, idling entire plant in favor of imported water).
Long Residence Times/Water Age	Hydraulic modeling	Identify potential stagnant areas and nitrification potential. Develop operational strategy to minimize water age.
System Operation Pumping/Storage Requirements	Hydraulic Model (in cooperation with MET's model)	Develop system operational strategy. Identify system HGLs and required system modifications.
Control of hydraulic transients	System Surge Analysis	Identify mitigation measures to protect system.

Issue	Recommended Study	Outcomes
Pipeline condition / pressure class incompatibility Impacts to existing facilities / local turnouts	Distribution System(s) Audit Pipeline Condition Assessment	Develop repair/ replacement program for pipelines and facilities identified as potentially impacted by hydraulic model.
DDW Requirements	Influence Model	Model anticipated system performance, water age and quality to satisfy DDW requirements
Water Quality Targets	Identification of Materials in Distribution Systems and Households Receiving Desalinated Water (Pipes, Appurtenances, Household Plumbing)	Pipe inventory and interior condition review
Corrosion Control Testing	Bench and Pilot Testing of materials not thoroughly tested, e.g., galvanized pipe and pipe tuberculation	Identification of conditions to address corrosion outcomes
Disinfectant Stability	Bench Testing of Chloramine Stability	Clearwell sizing; determination of DBP formation if pre-membrane chlorination is planned

1. Introduction

1.1 Purpose

On August 31, 2018, a Workshop was held between Municipal Water District of Orange County (MWDOC), Metropolitan Water District (MET), other stakeholders and engineering consultants to cooperatively identify and discuss the potential issues resulting from the introduction of desalinated water from two potential project sites (Huntington Beach to the north and Doheny to the south) into the Orange County region, which is currently served primarily by imported water supply from MET, and supplemented by local groundwater supply. This paper focuses on the **integration of desalinated water from the Doheny Desalination Plant into the South Orange County region**. Black and Veatch is preparing a similar analysis for the Huntington Beach Desalination Plant.

This document provides a review of available information, studies, engineering reports, and agency coordination to summarize and identify the required steps/approach to resolve key outstanding integration issues, including issues such as:

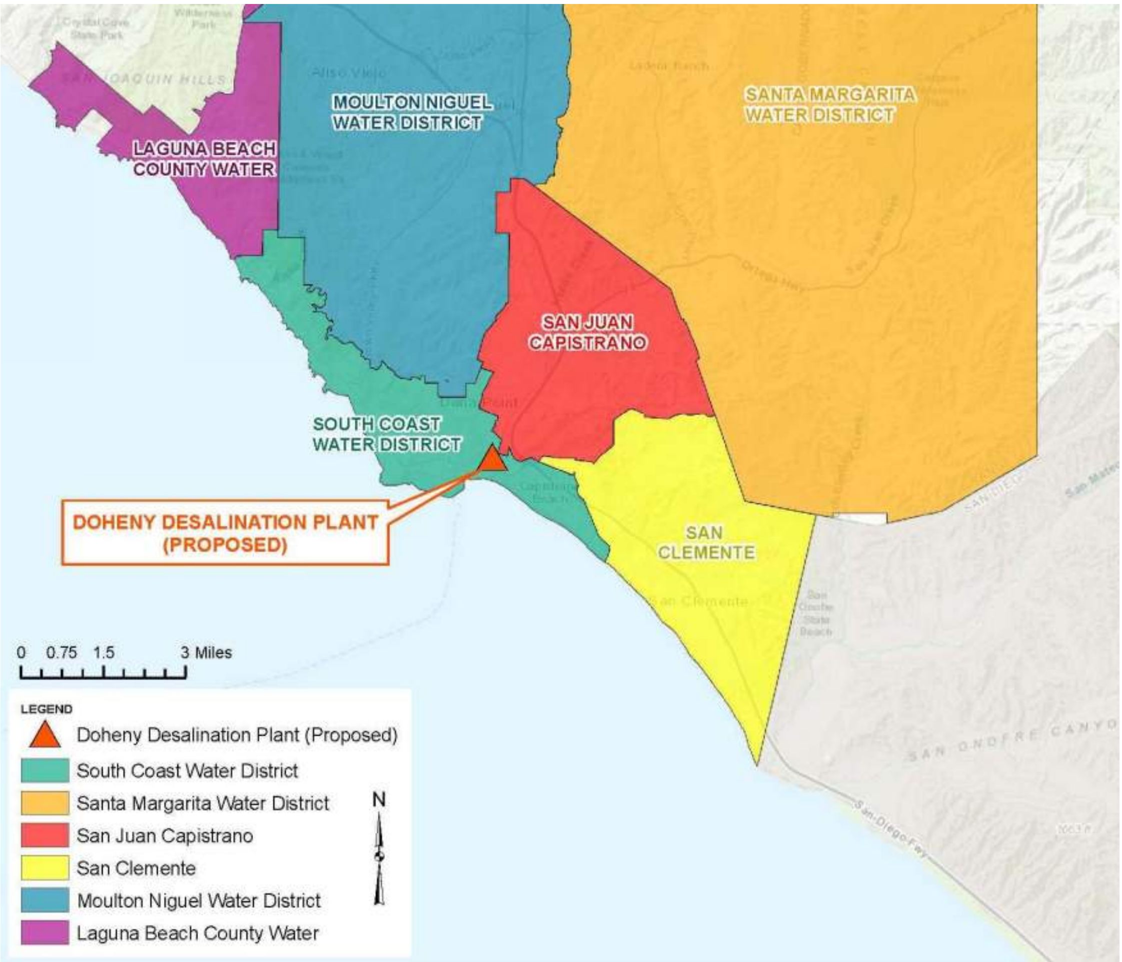
- MET, local agency, and regulatory issues of concern
- Managing operations and critical control points/plan
- Hydraulic and transient management strategy
- Mitigation of flow reversal patterns
- Low demand / low flow / water age issues
- Changes in water quality and blending models
- Impacts of varying pressures and qualities on existing pipeline materials
- Corrosion potential and water stabilization

The document concludes with a listing of recommended studies to understand/address these issues and support further project development.

1.2 Project Stakeholders

As a regional wholesale water supplier and resource-planning agency, MWDOC has spearheaded the 2018 Orange County Water Reliability Study to evaluate Orange County's current and future water demands and supplies to identify and "test" potential projects for improving the reliability of water supplies for the future. The Doheny Project, located in South Orange County (SOC) is one of the identified projects, with potential supply and reliability benefits to the following potential participating SOC agencies (see Figure 1-1**)**: South Coast Water District (SCWD), Laguna Beach County Water District (LBCWD), City of San Clemente, Santa Margarita Water District (SMWD) including the City of San Juan Capistrano, and Moulton Niguel Water District (MNWD). Because SOC's current primary source of supply is imported water, MET is also a key project stakeholder.

Figure 1-1: South Orange County Stakeholders



1.3 Plan for introduction of Doheny Flows

The currently proposed Doheny Desalination Plant will produce an initial capacity of 5 million gallons per day (MGD) and ultimate capacity of 15 MGD of a high-quality, locally-controlled, drought-proof potable water supply. This is equivalent to an annual production of 5,321 acre-feet per year (AFY) initial and 15,963 AFY ultimate (as noted in SCWD's Draft Environmental Impact Report, assuming approximately 5% downtime). The supply can potentially function as a continuous base-load supply into the SOC region replacing a portion of the current demand on imported supplies, and/or as an emergency backup water supply should a disruption of imported supplies to the area occur. The initial plant capacity of 5 MGD can be utilized directly by SCWD delivered within its own distribution system. The additional 10 MGD future capacity would be available to the other identified SOC stakeholders through regional transmission mains which currently convey imported water from MET.

The proposed plant location is on SCWD-owned property in the City of Dana Point, on the Pacific coast less than a quarter mile north of Doheny State Beach (see Figure 1-1). The site location is less than 1,000 linear feet from two regional transmission mains which currently deliver imported water from MET to the area: the Joint Transmission Main (JTM) and the Water Importation Pipeline (WIP). The location of these pipelines in relation to the Doheny site (plant facilities are green and blue shaded areas) is shown on Figure 1-2.

Figure 1-2: Regional Transmission Mains Near Proposed Doheny Site (PEIR, 2018)

Pumping into one or both of these regional transmission mains would be a potential method of integrating the Doheny supply into the regional system to replace imported demand. Other options may include new pumping, storage, and/or dedicated pipeline facilities integrated into the operation of the JTM and WIP to achieve the project goals.

SCWD has initiated environmental documentation on the Phase 1 project (5 MGD), issuing the Doheny Ocean Desalination Project Draft Environmental Impact Report, including public hearing on

June 26, 2018 and the 60-day public review period ending on August 6, 2018. According to SCWD's Infrastructure Master Plan Update dated October 2017, the estimated project schedule calls for completion of design in 2019 and construction completion by 2021 for the first phase, and expansion to full capacity by approximately 2026.

1.4 MET concerns

The commingling of MET and Doheny water within regional transmission mains and the replacement of the equivalent amount of imported MET water raises several potential issues of concern for MET, including:

- Integration of a new base-loaded supply into the SOC water system and potential impacts to operations at Diemer Plant due to reduction in demand.
- Impacts to existing infrastructure (pipe lining materials, other materials in contact with water) due to differences in water quality, or change in pressure or flow direction.
- Water quality and water age in MET facilities.
- Managing chloramine residual and minimizing pH/alkalinity changes between supply sources to avoid negative water quality impacts where the sources blend or are alternate.
- Management of calcium carbonate precipitation potential (CCPP) levels to mitigate potential for corrosion and/or precipitation.
- System operational integrity and implementation of critical control points/plan to address and mitigate quality, hydraulic, and operational issues.

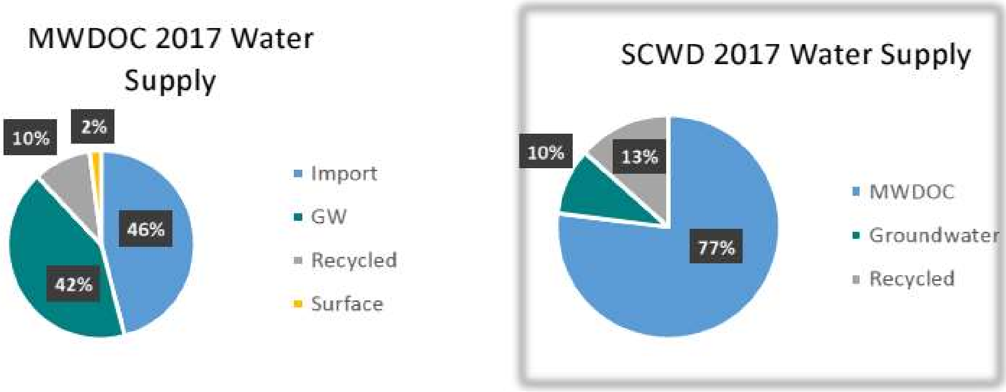
2. Operations

2.1 Current South Orange County Operations

2.1.1 Source waters

Imported water from MET is a critical source of supply for the Orange County Region. As illustrated in Figure 2-1, in 2017 imported water comprised the primary source of water supply in MWDOC's service area at 46%, followed by groundwater at 42%, recycled water at 10%, and surface water at 2%. For the SOC region, the general underlying geology is much less conducive to aquifer storage, and the resulting limitations on available groundwater supply results in imported water comprising an even larger majority of the water supply portfolio of the SOC water agencies. As an example, imported water from MET (through MWDOC) provided 77% of SCWD's 2017 water supply (see Figure 2-1).

Figure 2-1: MWDOC and SCWD Current Water Supply Portfolios (PEIR, 2018)



The high reliance on a single source of supply is a key driver for the Doheny project, aimed at providing an alternative source of supply to improve regional water supply reliability.

MWDOC modeled estimated SOC water supply needs in the 2018 OC Water Reliability Study, forecasting an increase of SOC water demands from 117,000 AFY in 2020 to 125,000 AFY in 2050, for an area encompassing the potential participating SOC agencies outlined in Section 1.2, as well as Emerald Bay Service District, El Toro Water District, Trabuco Canyon Water District, and the easterly portion of Irvine Ranch Water District. The 2015 Urban Water Management Plans for each of the six stakeholder agencies were reviewed to determine their collective portion of this overall SOC regional demand. Table 2-1 lists the actual total annual water demand and annual imported water use for these agencies.

Table 2-1: 2015 Imported Water Use for Potential Participating SOC Agencies

Agency	2015 Demand (AF)*	2015 Actual Imported Supply (AF)	% Imported
SCWD	5,915	5,737	97%
SMWD	26,910	26,910	100%
MNWD	26,824	26,824	100%
San Clemente	9,035	8,917	99%
San Juan (2010)	8,359	6,379	76%
LBCWD	3,630	3,630	100%
Total	80,673	78,397	97%

* Potable and raw water (not including recycled water demand)

From the basic viewpoint of annual totals, it appears that these agencies would be capable of utilizing the proposed ultimate annual production of 15,963 AFY from Doheny to replace a portion of imported demand. Doheny could then potentially provide up to 15,963 of the 80,673 AFY demand with a local, reliable, drought-proof supply. The specific plan for deliveries would depend on additional factors, such as seasonal demand patterns and coordination with the commitments for other base-loaded supplies.

2.1.2 Pipelines and flow patterns

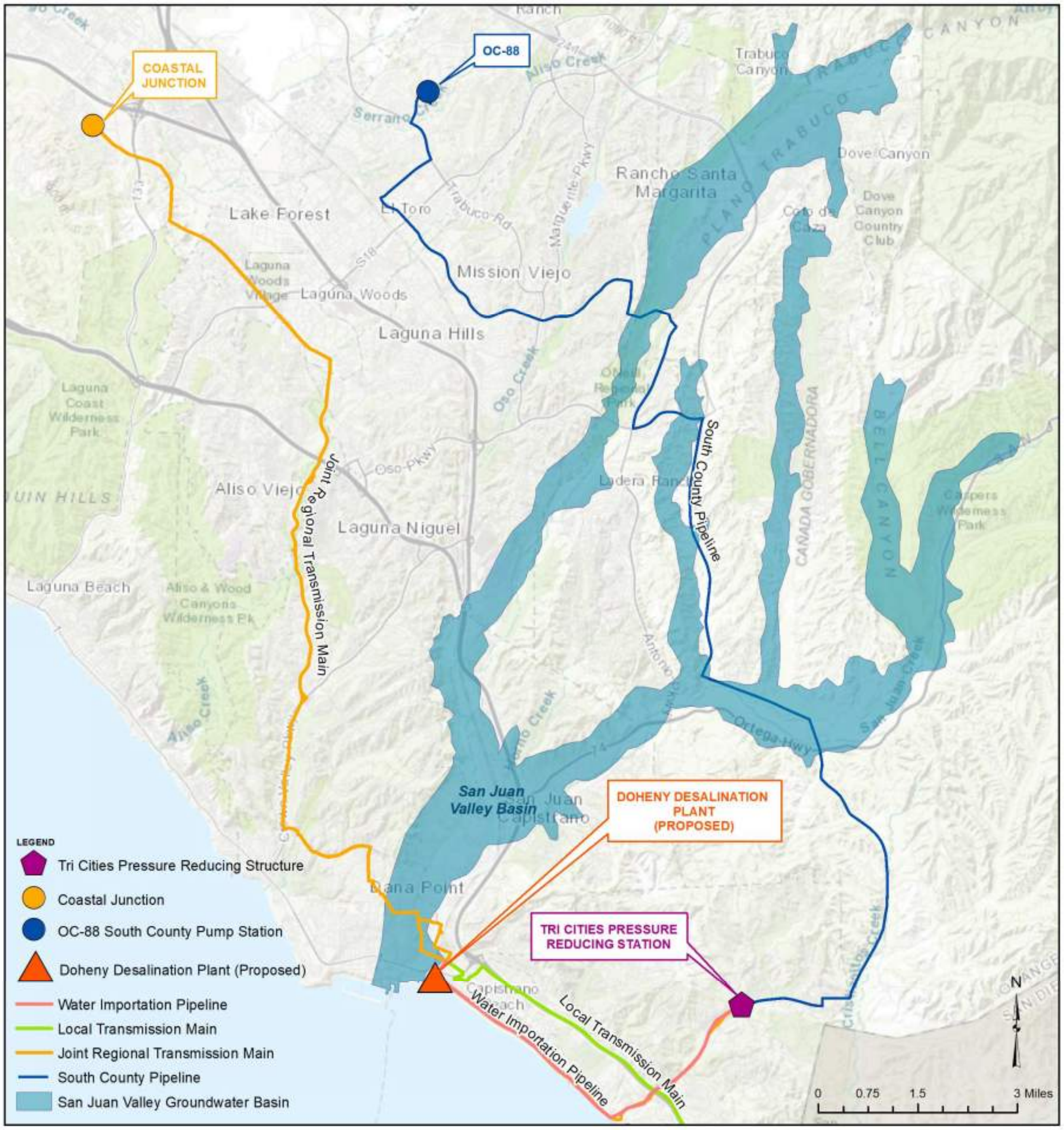
The imported water supply provided by MET to Orange County is treated at the Robert B. Diemer Filtration Plant located north of Yorba Linda. Treated water is conveyed to the SOC agencies through two primary feeder lines:

- ***East Orange County Feeder (EOCF) #2 system:*** conveys water to the Coastal Junction, with turnouts to the Aufdenkamp Transmission Main (ATM) which runs south to Laguna Beach, and the Joint Transmission Main (JTM) through MNWD into SCWD's service area, where it turns into the Local Transmission Main (LTM) and heads south along the coast toward San Diego County.
- ***Allen-McColloch Pipeline (AMP):*** conveys water through the South County Pump Station (OC-88) in Lake Forest, to the South County Pipeline (SCP) through SMWD's service area into San Clemente, where it turns into the Water Importation Pipeline (WIP) heading north along the coast toward Dana Point.

In addition to the Diemer supply, the Baker Treatment Plant, operated by IRWD, provides additional water supply to the region. Baker receives untreated imported water from MET through the Baker Pipeline, which is connected to MET's Santiago Lateral via the OC-33 turnout, and treats this surface water supply to drinking water standards, after which it is introduced into the SCP. Baker Treatment Plant also can treat local surface water supplied from Irvine Lake, which is delivered via the Irvine Lake Pipeline and Baker raw water pump station, which is located adjacent to MWDOC's WEROC facility off of Jamboree Road.

This system of regional imported potable water pipelines is illustrated in Figure 2-2. Under current operations, all flows in these regional pipelines originate at Diemer or the Baker Water Treatment Plant (typically supplied with MET untreated water) in the north, and flow in one direction within the pipelines (generally south).

Figure 2-2: Regional Potable Water Transmission Mains Near Doheny Site



2.2 Changes in operations with introduction of Doheny

The introduction of Doheny to the system provides a new source of supply at the southern end of the system; however, it is expected to result in relatively minor changes in the overall operation of MET's system. It is estimated that at ultimate capacity, Doheny will be capable of providing approximately the full low demand flows for the JTM and the WIP and approximately one-third to one-half of the high demand flows (refer to Section 3.1.1 for discussion on flows). Flow into the JTM is controlled at the Coastal Junction within IRWD's service area, and flow into the WIP is regulated by the Tri-Cities

Pressure Reducing Structure (TCPRS) at the terminus of the SCP in the City of San Clemente. The location of these key facilities within the system are shown on Figure 2-2.

As an example, if Doheny is utilized as a base-loaded supply for the JTM and WIP, the TCPRS and Coastal Junction turnout can be used on an as-needed basis, similar to PRVs connecting a higher-pressure zone to a lower-pressure zone, which would be coordinated through call-in pre-scheduled flow changes. The installation of a pressure reducing station or similar structure at the Coastal Junction may provide this control. Additionally, the structure would simultaneously prevent flows from Doheny from propagating along the JTM upstream into MET's system, as would the TCPRS along the WIP/SCP, alleviating a possible concern that MET has previously expressed regarding introduction of other water supplies into their system. *Recommendation: Evaluate facility requirements to control flows and protect MET's systems (for example, installation of PRS at Coastal Junction to isolate Doheny water from EOCF#2).*

Operational impacts to MET upstream of the SOC region will likely also be minor and may consist of impacts at the Diemer plant and in the East Orange County Feeder #2.

- ***Diemer:*** There could be minor changes in the potable water production at Diemer due to the small reduction in demand if other demands cannot be found to make up the difference. Although the potential impacts of a reduction in demand of 15 MGD are likely to be relatively minor when compared to the overall capacity of 520 MGD at Diemer, the potential impacts should be evaluated. Furthermore, should multiple regional projects be implemented, it will be significant to consider and analyze the overall reduction. Refer to additional discussion in Section 2.3.1.
- ***EOCF#2:*** If the total demand in the EOCF#2 remains the same then a small increase in the overall HGL in the EOC and downstream pipelines may result. Due to the small amount of overall flow, these increases would be expected to be quite minor, and will be verified through the proposed hydraulic modeling of the system. If the production is reduced, then the system may not experience any changes in the overall HGLs in the pipelines.

2.3 Plant Operating Demand Options

Worldwide, there are various operational philosophies that are applied to seawater desalination plants. In some areas, where alternate water supplies are scarce or unreliable, the desalination facility will operate effectively as a based load water production facility, in continuous operation. In other areas, where the desalination plant is supporting a shortfall in existing supplies, the plant may run intermittently for periods as required. This intermittent operation may be on a seasonal basis (for example in areas where surface water supplies are limited in regular dry periods) or during drought periods. In some cases, desalination plants are even brought on and off line frequently to match preferred diurnal power tariff periods.

Some examples are summarized in the Table 2-2:

Table 2-2: Plant Operating Scenarios

Operating Scenario	Examples	Operating Issues
Baseline Continuous or Near Continuous Operation at Full Capacity	Middle East Desal Facilities Singapore Perth Carlsbad	Corrosion Management. RO train duty rotation.
Operation at Varied Flow Rate/Reduced Flow Rate	Tampa Bay	Duty rotation of RO trains that are not required. Management of stabilization system at flow changes. Management of different blend ratios. Higher energy per unit water produced.
Operation Seasonally, During Drought Conditions	Sydney/Adelaide Desalination Plants Tampa Bay	Long term preservation of membranes. Long term preservation of mechanical equipment. Instability of stabilization process during restart.
Intermittent Operation – Power Tariff	Gold Coast Desalination Plant Tampa Bay	Multiple starts per week. Varied/interrupted blends. Impacts to membrane pretreatment stability.

2.3.1 Baseline Operation of the Desalination Plant

Baseline or continuous operation of a seawater desalination system provides the most stable operating scenario in terms of integration with existing supplies. Given that the cost of operation of seawater desalination is typically one of the highest in comparison to most other options in a utility's portfolio, it can generally be assumed that this scenario most often occurs when other lower cost options are not available in sufficient quantity.

Stable, effectively steady state operation is possible at this condition with the system operating at a stable flow rate, with all duty RO units operating at the plant. The steady flow rate provides the best conditions for chemical dosing and control of water stability and allows greater certainty on managing blending into distribution systems.

At the plant itself, duty rotation of RO units (assuming there is some standby capacity) will usually be performed to provide even wear on mechanical equipment, ensure RO membranes are maintained in a wet condition, and importantly that all areas of feed and brine pipework are regularly exercised to avoid stagnant seawater exacerbating corrosion. Pretreatment systems, especially those utilizing flocculation/sedimentation processes, also benefit from more consistent flow conditions.

While this operating scenario may seem optimal for the desalination plant itself it must be remembered that the cost of operation of the desalination facility is still sufficiently high such that if alternative sources are available, they will likely be preferred. While this may increase the burden on the desal plant operations, the benefits of lower cost water often outweigh the additional risks and costs. That is, base loading the system using the cheapest water available, then supplementing with expensive water (desal). MWDOC will continue to have to pay for Diemer costs, including stand-by costs (a premium to maintain reliability). MWDOC should consider the best strategy that balances these issues. *Recommendation: Perform a cost/benefit analysis to evaluate the modification of operations at Diemer (if, at some point, the combination of proposed local supplies results in a stranding of assets at Diemer, which still have to be paid for), versus maintaining the desalination plant(s) in standby "pickled" mode for some portion of the year.*

2.3.2 Operation at Varying Flow Rate / Reduced Flow Rate

Many seawater desalination plants operate to provide additional water to meet demands in distribution systems, and they may operate at varying flowrates either seasonally or even diurnally. One of the limitations of the reverse osmosis system which is at the heart of the desalination system is that the process requires near constant flow per unit. This being the case, flow can only be adjusted through the plant on an incremental basis, that is by bringing trains on and off-line. Therefore, changes in flow rate tend to be step changes based on the number of trains brought on or off-line.

These fluctuations in flow rate may present challenges controlling dosing to maintain stability indices, although any fluctuations will be for a short duration only during and after the flow step change. More importantly, implications for blending in the distribution system and management of these step changes will need to be considered.

At the plant, if not all RO units are required, duty rotation and flushing will be required to both keep membranes wet and regularly flush pipework to avoid stagnant seawater which can exacerbate corrosion. Typically, the most efficient energy performance of the desalination plant (energy per unit of flow) is achieved only at full flow.

Another issue that may arise during low demand periods is maintaining water quality in the transmission system due to long residence times. Localized areas of lower flows will result in longer transient times and reduced residuals that could adversely impact both MET and local system disinfection residuals. It was noted at the Workshop that MET criteria calls for maximum retention time in their system of 3 days to minimize nitrification. One possible method to alleviate concerns about water age is to periodically adjust the source of supply, such that water changes direction periodically and turns over to avoid water quality issues. Also noted at the August 31, 2018 workshop was the recommendation to conduct system hydraulic modeling during low demand periods in two steps: first in MET's system without the new local sources, and second including the new local sources. A comparison will allow pinpointing of vulnerable areas, allowing for additional local system modeling to determine if water ages are greater than 2 or 3 days, and the testing of potential scenarios to decrease water age. *Recommendation: Conduct system hydraulic modeling in steps, allowing for comparison of results with and without desal supply, to identify areas where water ages increase significantly.*

2.3.3 Operation Seasonally or During Drought Conditions

Some seawater desalination plants have been built to provide water during drought conditions and when these conditions cease they are no longer required to run. An example of this is the Melbourne and Sydney desalination plants on the eastern seaboard in Australia. Under these conditions, the plants may be placed in to a long term shut down condition (sometimes referred to as mothballed) where membranes are either preserved in chemical solution or removed, mechanical equipment kept in a standby mode, analyzers and instruments mothballed, water drained from storages and pipework and intakes and outfalls maintained to minimize blockage from marine growth.

This mode of operation presents its biggest challenges during restart, which will be an effective recommissioning of the facility. Periods of re-adjustment of chemical dosing for stability indices and re-integration to the distribution system will be required as for a new facility. In addition, depending on the period of time the plant has been in long term shut down, there may be a re-learning period due to loss of knowledge and operational experience at the facility.

2.3.4 Intermittent Operation – Power Tariffs

In some systems, utilities take advantage of off-peak lower power tariffs and operate desalination facilities during lower power demand periods. An example of this is the Gold Coast Desalination plant in Australia which operates during late night lower power tariff periods. This operating scenario is similar to varying flow rate, with consideration required to the impact of frequent (often daily) start up and shut down of the facility. This will provide daily step changes in blend ratio from the plant which will need to be considered along with a short term instability in dosing for stability indices.

2.4 Critical Control Points Plan

The Hazard Analysis and Critical Control Point (HACCP) methodology has been adopted internationally by a number of countries to manage microbiological and chemical contaminants in water treatment systems, including recycled water systems and seawater desalination plants. HACCP is a logical, scientific process control system designed to identify, evaluate and control hazards, which are significant for food safety. The purpose of a HACCP system is to put in place process controls that will detect and correct deviations in quality processes at the earliest possible opportunity. It focuses on monitoring and maintaining the barriers of treatment, rather than on end of pipe sampling and testing.

The HACCP system identifies critical control points (CCPs) as points in the treatment process that are specifically to reduce, prevent, or eliminate a human health hazard and for which controls exist to ensure the proper performance of that process. Highlighting these points assists both operators, regulators and other stakeholders to place a primary focus on public health, as distinct from other important operational elements.

For a seawater desalination plant, these critical control points could be:

Table 2-3: Critical Control Points

Critical Control Point (CCP)	Critical Monitoring Parameters	Risk Mitigated
Pretreatment filtration (either floc/sed filtration or membrane filtration)	Turbidity or membrane integrity	Microorganisms
First Pass RO	Permeate conductivity	Microorganisms. Inorganic constituents.
Second Pass RO	Permeate conductivity	Inorganic constituents (boron, bromate – resulting from later oxidation of bromide)
Stability Dosing	pH, Hardness Alkalinity	Lead and copper rule. (see discussion in section 4)
Final disinfection	Chlorine	Microorganisms

Transparent communication of the performance of each barrier, as determined by its critical monitor, is a very helpful indicator for MWDOC that the desalination plant is operating to expectations. In particular the stability dosing parameters can give a high level of confidence for blending into the distribution system.

Consideration should be given to live communication of the status of these CCPs via shared SCADA screen or other on-line communication device as part of an effective operations communications protocol.

2.5 Effective Communication at the Operational Interface

An important operational element in the integration of a desalination plant is the development of an operating protocol between MET and the desalination plant operator. The purpose of the protocol is to set out the allocation of responsibility between the parties for the supply of desalinated water and ensure that risks are effectively managed. Key elements of the protocol should include:

- ***Clear definition of interface points.*** That is, a clear articulation of the physical location at which the water transitions from the responsibility of one party to another. This should be described in terms of process and instrumentation diagram (P&ID) as an identified termination point, including a piping layout drawing with GIS (geographic information system) coordinates. For example, this may be at a fence line, or a specific flange in a pipeline. A schematic diagram included within the protocol is helpful. While this is likely to be clearly identified in any operating contract, it is important to include as a reminder in operating protocols.

- ***A communication protocol.*** Communication between parties must be undertaken regularly and in a clear and efficient manner. A communication protocol may include regular meetings of operations staff and the discussion of water quality, planned changes to infrastructure, planned maintenance activities and a review of that period’s performance. Valuable communication may also include the sharing of water quality data, including any on-line data that may be available at the operational interface. This will allow MET to better anticipate any issues in terms of demand that may occur. Orange County Water District and Orange County Sanitation District have long managed effective communications across the wastewater treatment to advanced water treatment interface for both the Groundwater Replenishment System and preceding Water Factory 21 to great effect. A high level of transparency and spirit of cooperation has been critical to the system's success.

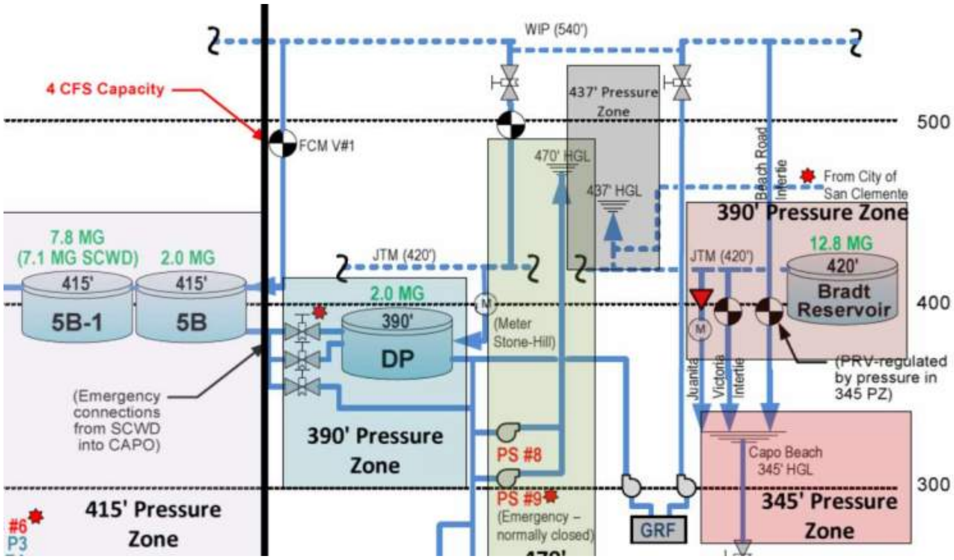
- ***Regular reporting of water quality and production.*** This is the "business as usual" content of communication and provides an ongoing understanding between entities of the key aspects of operation. For example, it will be key to communicate water demand changes from end users, and water quality variations from Diemer (as may occur dependent on Colorado River / State Project Water blend changes).
- ***Management of maintenance schedule.*** As noted above, maintenance activities at either side of the operational interface can impact operations. The sharing and regular updating of planned maintenance activities – over a period of 6 to 12 months can provide certainty for planning and minimize unforeseen impacts. Benefits of aligning maintenance (for example coordinating downtime) can improve overall system production.
- ***Coordination of Incident and Emergency Management.*** Effective coordination between operational entities in the event of an emergency event are critical. The co-ordination plan should include responses to supply interruption, circumstances under which water cannot be accepted (either not acceptable to the advanced treatment system or not acceptable to drinking water/distribution, management of water quality incidents and critical control point failures.

3. Hydraulics

3.1 Pumpback

Product water from the Doheny plant will be stored in an on-site reservoir and must then be pumped into the regional system. As noted previously, the nearest regional pipelines to the plant site are the JTM and the WIP, which in this area have an approximate HGL of 420 feet and 540 feet, respectively, as shown on Figure 3-1 from SCWD's Infrastructure Master Plan. Further information on the HGLs can be observed from Figure 5 of the Tri-Cities Municipal Water District Water Supply System Operations Description (included in Appendix C), illustrates the HGL upstream and downstream of the SCWD connection points in both the JTM (formerly known as the Tri-Cities Transmission Main) and the SCP/WIP.

Figure 3-1: HGL in Regional Transmission Mains at SCWD Turnout Locations (from Fig 402, SCWD IMP, 2016)



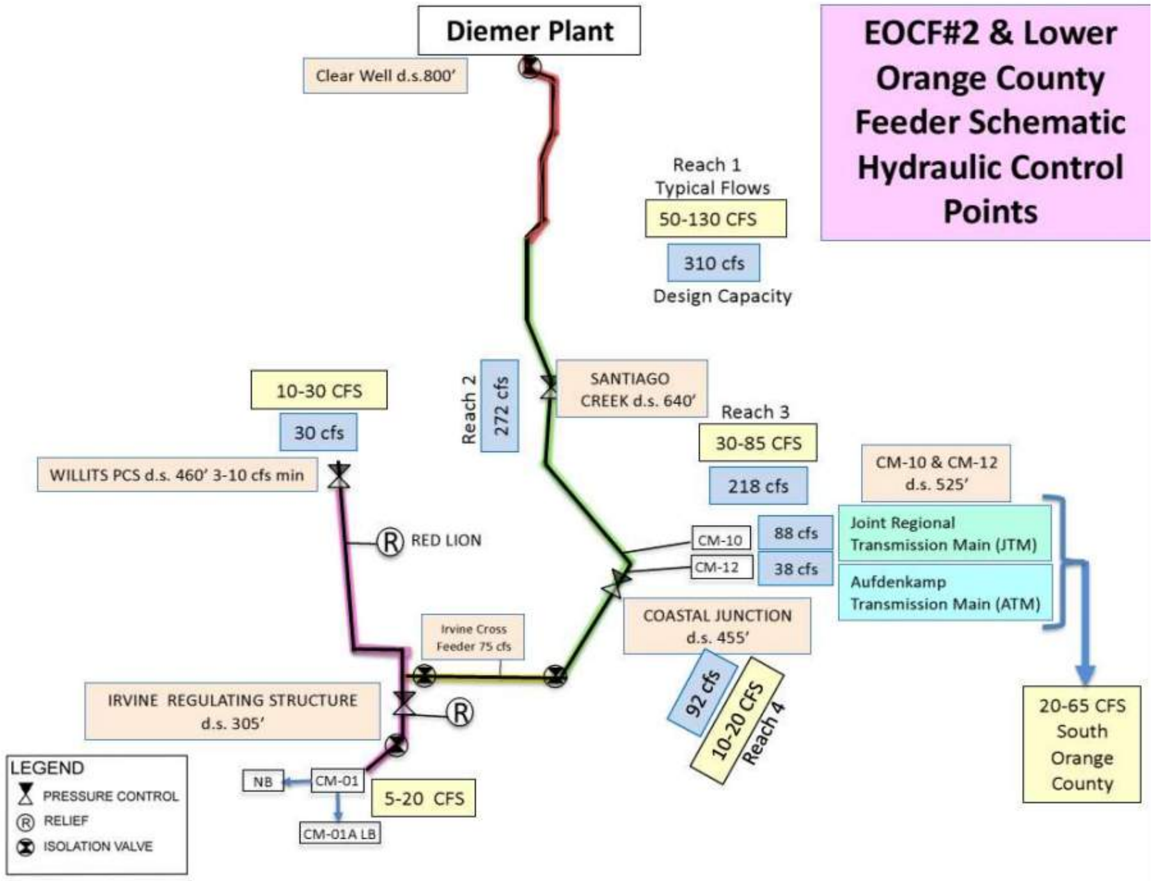
Due to the HGL elevation difference between the WIP and the JTM, it is unlikely that water from Doheny will be able to be delivered to both transmission systems without the installation of separate pump stations. Only two turnouts on the WIP are currently supplied flow with an HGL elevation of 500 ft or less, and all four that are located “downstream” of the TCPRS are at 600 ft or less. The entire JTM is currently supplied flow with an HGL elevation of approximately 520 ft or less.

The proposed pump station(s) may result in the reversal of the current flow direction in parts of the JTM and the WIP. Additionally, the pressures at the turnouts on both pipelines may increase over current levels. In order to maintain existing delivery pressures at the turnouts, modifications or changes to the operation of the valves at the turnouts may be required. The required modifications would be evaluated at each individual location, and in some cases, it would even be possible that the higher pressures may be advantageous to the users by reducing or eliminating the need for booster pump stations. *Recommendation: Perform detailed hydraulic model of the system with introduction of new flows to identify the anticipated pressures at each turnout and the required facility modifications.*

3.1.1 Sizing/flows

From Figure 3-2 below provided by MWDOC, the total typical demand through both the JTM (Turnout CM-10) and the ATM (Turnout CM-12) ranges between 20 and 65 cubic feet per second (cfs), with design capacities at 88 cfs and 38 cfs, respectively.

Figure 3-2: EOCF#2 Hydraulic Control Points



Assuming the demand ratios are the same as the capacity ratios, demands of between 14 and 45 cfs would be expected in the JTM. At the proposed regional capacity of 15 MGD (23 cfs), Doheny could potentially provide approximately 50 percent of the high range demand and in excess of 100 percent of the low range demand in the JTM. For the four potential turnouts along the WIP, it is possible that 35 percent of the high demands and 100 percent of the low demands could be met by Doheny. These projections should be confirmed based upon historical and projected demands at the turnouts and incorporated into the proposed hydraulic modeling, including considerations for seasonal demand variations and commitments to other supplies (Baker, groundwater).

The location of key facilities and turnouts are illustrated on Figure 3-3.

Hazen

7700 IRVINE CENTER DR
SUITE 200
IRVINE, CA 92617
(949) 557 - 8549

MWDOC

MUNICIPAL WATER DISTRICT
OF ORANGE COUNTY

INTEGRATION OF DOHENY DESALINATED WATER

KEY REGIONAL FACILITIES AND TURNOUTS

DATE: APRIL 2019

FIGURE 3-3

Introducing Flow into the WIP: Doheny flow in the WIP could serve the four turnouts along the WIP downstream of the TCPRS. The TCPRS could be operated to provide supplemental flow from MET into the WIP during periods when demand is greater than Doheny supply capacity and be closed during low demand periods. This operation could result in slightly higher HGLs in the SCP; however, the Regulating Reservoir located on the SCP upstream of the TCPRS maintains fairly constant HGLs in the SCP and the resulting HGLs likely would be within typical ranges normally present in the pipeline. It may also be possible to provide flow upstream of the TCPRS, potentially as an emergency supply, by utilizing the existing bypass and new booster facilities to pump back into the SCP at higher HGL. However, introducing project flow further upstream into the MET system may not be preferred by MET.

Introducing Flow into the JTM: In order to introduce flow into the JTM and reverse flows toward the turnouts to be served, the HGL in the JTM at the connection points is estimated to be approximately 550 feet to 600 feet. This would impact the connection to the Bradt Reservoir, which has an HGL of 430 ft, and the SCWD 5B Reservoir at 415 feet, and each would therefore require a pressure reducing structure. Additionally, the presence of the surge tower on the JTM near the ETWD turnout will limit the pumpback capability of the station north of this point. The surge tower has an overtopping elevation of 545 ft. The anticipated hydraulics in this area will likely result in an HGL elevation at this location near or slightly greater than current levels.

Recommendation: Hydraulic modeling of the system should be performed to determine the required pumping head and pump configuration for the pump station to ensure the required flows when supplemented by MET can be supplied. The analysis should include consideration of a possible new flow/pressure control facility, flow direction changes, turnout setting changes, and other parameters necessary to ensure the delivery of Doheny water to the system users in a way that limits potential conflicts between all of the stakeholders. Ideally, this would include the impacted MET facilities and pipelines. Perform, or support MET's efforts to perform its own hydraulic modeling to determine the effects on their system.

3.1.2 Locations

As mentioned previously, the initial 5 MGD (5,321 AFY) may be immediately utilized by SCWD's system, although this may be limited to approximately 3 MGD during low demand winter months. The location of Doheny within the SCWD service area, and SCWD's adjacent turnouts of both the JTM and WIP are such that SCWD is a logical choice for Doheny service. The remaining 10 MGD (10,642 AFY) to 12 MGD could potentially continue to travel within the JTM and WIP to the adjacent participating agencies. Based upon the hydraulic conditions at the plant and within the JTM and WIP, flows could be delivered to the City of San Clemente through the WIP, and to the City of San Juan Capistrano and MNWD through the JTM. Flow could also be transferred to LBCWD through SCWD's existing interconnection, which would most likely be an emergency/backup supply. In order to serve SMWD, a separate pumping station and transmission line would likely be required due to the location of the TCPRS, or it would have to be accomplished through an in-lieu transfer with another agency.

3.2 Potential concerns

3.2.1 MET system impacts

Previous work with MET has shown that they have a history of not allowing (whenever possible) pumping into their system from outside systems. This has been to avoid potential hydraulic transients, contamination issues, mixing of water of various sources, and unintended consequences to end-used plumbing facilities with their system. More recently, they have approved a Policy allowing water to be pumped back into the MET system under emergency conditions when MET cannot meet required demands.

The design of the system would consider MET's preferences, and alternatives to minimize potential impacts on MET's system could be analyzed and incorporated if deemed appropriate. An example would be the installation of a new flow/pressure control facility at the Coastal Junction turnout to the JTM. This would prevent flow from Doheny from entering MET's system, and imported flow would only be delivered when demands greater than available Doheny supply was required in the JTM and downstream system. The TCPRS on the SCP/WIP would perform a similar function, only called upon to provide flow when demand could not be met by Doheny. With these two facilities in place, there would be no potential mixing of MET and Doheny water in MET's system upstream of the Coastal Junction and TCPRS.

The potential impacts at Diemer were discussed in Section 2.2. Potential water quality concerns in the JTM and WIP are discussed in Section 4. The recommended hydraulic modeling of the system and the simulation of the possible flow and pressure operating scenarios under which the system is anticipated to be operated, in conjunction with MET's modeling will evaluate and help minimize any potential impacts.

3.2.2 Transients/surge

The installation of a pump station(s) at Doheny to deliver flow into the JTM and/or WIP will introduce a potential new source of pressure surges to the system. Pressure surges are created every time a pump or pumps at the pump station start up, shut down, or experience a loss of power. These pressure surges will propagate out into the JTM and the WIP, potentially creating adverse pressure surges in the system that will have to be mitigated.

Pressure transients, or surges, are associated with a sudden change in velocity within a pipeline. Addressing pressure surges is always best accomplished at the source of the pressure surges whenever possible. The primary source of pressure surges in this part of the system will be the pump station(s) associated with the Doheny facility.

The pump station connection to the JTM would likely be located at the treatment plant property or at the low point near San Juan Creek. Upon the sudden loss of power to the pumps, a pressure drop wave will propagate out from the pump station and into the JTM. The magnitude of the pressure drop is dependent on the "instantaneous" change in flow velocity created by the loss of power and the pipeline material into which the pressure drop wave will travel. The pressure drop wave will travel both north and south along the JTM, with the following effects:

- Assuming a flow rate of 23 cfs with half the flow going each direction prior to loss of power, the pressure drop created (assuming “rigid” pipe, i.e., concrete) could be between 150 ft and 300 ft head. This will likely be sufficient to create negative pressures in the JTM in both directions.
- If there are any vacuum relief valves along the line, they will open when the pressure falls below atmospheric pressure and admit air into the pipeline and “pin” the HGL to the elevation of the vacuum valves. Based on the profile of the JTM and WIP as shown in the previously referenced Figure 5, it is likely that significant parts of the lines will still experience negative pressure conditions.
- If the minimum pressure were to fall low enough as to reach vapor pressure, it is possible that a vapor cavity will form within the pipeline. When the vapor cavity is repressurized, it will collapse creating potentially extremely high localized pressures that could damage the pipeline.
- When the pressure drop wave reaches a reflection point it will be reflected back as a repressurization wave if it reflects off a constant head location such as a tank or a reservoir, or as an additional pressure drop wave if it reflects off a closed or partially closed valve. Subsequent reflections may result in pressure upsurge waves that could create sufficiently high pressures as to overpressurize the pipelines.
- Negative pressures within the pipeline may also raise the possibility of pathogen intrusion. The pressure differential across a pipeline subjected to negative pressures will allow for external contaminants to infiltrate the pipeline due to the opening of vacuum relief valves and via holes, cracks, loose joints, etc. in the pipeline.

Thus, the sudden loss of power to a pump station is often seen as having the potential to create the most adverse pressure surges in a system.

The pressure surges generated by normal pump start up and shutdown are generally easily controlled through the use of variable frequency drives or pump control valves that can be used to gradually shutdown or start up the pumps, thus eliminating any sudden change in flow and pipeline velocity and thereby significantly reducing any pressure surges created.

An additional source of pressure surges in the system is the opening and closing of the valves on the system. This would include valves at the TCPRS, the turnouts on the system, as well as any potential new valves that are installed as a result of the Doheny facility. While pressure surges caused by valves may be as significant as a pump station, preventing measures are more easily implemented. If designed and implemented properly, valves should not create any adverse pressures within a system. A variety of methods can be employed, including:

- Proper Timing of the Valve Operation: When opening and closing valves, from a surge perspective, slower is preferred. The slower the valve is operated, the smaller the change in velocity of the flow and the subsequent pressure surge that is created.
- Proper Valve Selection: Ball, plug, sleeve, and globe style valves have much better flow control characteristics when operating than do butterfly or gate valves and are thus better

for controlling flow. The latter should be used primarily for isolation purposes where flow control is not required.

- Proper Valve Sizing: Proper sizing reduces the possibility of creating adverse pressure surges, as does sequencing of valves that operate together or in series.

Eliminating adverse pressure surges within the system requires installation of mitigation measures either at the pump station or along the impacted pipelines. Table 3-1 presents some of the many possible devices and measures that can be used to eliminate adverse pressures in a system.

Table 3-1: Alternative Surge Protection Methods

Methods	Considerations
• pressurized surge tanks • standpipes • one-way tanks • vacuum relief valves • increased polar moment of inertia (i.e., flywheel) • surge relief valves • surge anticipator valves • pump control valves • pump bypass valves	• controlling both high- and low-pressure problems • space considerations • proper sizing • proper location within the system

Performing a detailed pressure surge analysis of the system will allow for the proper design of mitigation measures for the system. Such an analysis would simulate pump station operations (power failure, shut down, and start up) and valve operations (opening and closing) that could create adverse pressure surges in the system. These analyses will identify the potential surge issues within the system at which point the proper surge protection measures can be designed. This would include type, sizing, location, and set points as required for them to perform properly.

Of particular interest to MET is the installation of tanks within the system to assist in controlling pressure surges generated by the Doheny pump station. Performing a pressure surge analysis is the only way to determine if the installation of tanks will provide the required protection of the system from adverse pressure surges. The modeled characteristics and location of predicted surge events will be the driver of whether tanks will be beneficial for surge protection.

Pressurized surge tank. If a tank were considered, the likely location for a pressurized surge tank is on the downstream side of the proposed pump station. This location will address the pressure surges created by the pump station at the source. If required, it will reduce the magnitude of the initial downsurge pressure wave created by the loss of power or shutdown of the pump(s) at the station, potentially eliminating the possibility of negative pressures and vapor cavity formation in the system piping. It will also reduce any return high pressure upsurge wave that would subsequently be created, reducing the possibility of overpressurizing the pipelines.

Because the existing transmission mains contain multiple high and low points, it may be necessary to install additional devices elsewhere along the pipe alignments. Possible locations for the installation of tanks is at the local high points where it is likely that vacuum relief valves may already be installed. In this case, one-way tanks would be the likely option. These tanks would allow water into the pipeline upon a reduction in pressure, preventing water column separation and the introduction of air to the system. Upon repressurization, a check valve would close preventing water from reentering the tank. Once the system is brought back online, an altitude valve would refill the tank to a preset level, allowing for proper operation in a subsequent surge event.

Surge tower. The installation of surge towers similar to that which is on the JTM do not appear feasible due to the height required to prevent overtopping as a result of the anticipated hydraulic grade line required to deliver flow to the demands along these lines.

Storage reservoir. The surge tower on the JTM is located at the high point on the pipeline and would be a possible location for the installation of a storage reservoir. This would help to stabilize the operation of the pump station and the interconnection to the MET system at Coastal Junction by providing a constant head to which each would deliver flow. It would prevent pressure surges created by the pump station from propagating back into the EOCF#2. However, it would not provide protection to the JTM between this location and the pump station created during the initial loss of power.

Recommendation: Perform a detailed pressure surge analysis of the system to determine the proper mitigation measures to eliminate adverse pressure surges in the system and protect system from possible damage and failure.

3.2.3 Pipeline condition assessment

A critical issue for Doheny integration is the condition of the existing pipelines and how the existing infrastructure can handle the anticipated new steady state operating pressures required to deliver the flow and potential surge pressures resulting from the operation of the pump station. As currently configured, the system operates under gravity flow conditions without any pumps delivering flow into the system and facilities are subjected only to static pressures. Under pumping conditions, the steady state HGL would need to be increased to overcome not only the static pressure but also the friction and minor head losses associated with the system. This could result in pressures that may exceed the rated pressures of the pipelines. The pipeline material, age, class, and condition all will affect the ability to withstand changes in currently operations.

Due to the higher steady state operating pressures, a thorough condition assessment will have to be performed. With the JTM approaching 60 years old and the other lines similarly aged, natural deterioration of the lines and their ability to handle even their original rated pressure may be compromised. Additionally, valves and other appurtenances on the line will need to be evaluated to be sure they will be able to handle the increased operating pressures.

When operating under gravity flow conditions, the only source of pressure surges in the system is valve operations. As was previously discussed, these are generally easily controlled through the slow opening and closing of the valves as well as proper sequencing of their operations. The pressure surges associated with the operation of valves can be kept such that they only slightly exceed the static pressure in the system. With the addition of a pump station at Doheny, the pipelines will have to withstand not only the higher steady state operating pressure but also the additional surge pressure that would exceed the already higher steady state pressure.

Recommendation: Perform a thorough audit and assessment of system assets, including age, material, class, condition. Cross-reference with the findings of the hydraulic analysis to identify deficiencies and create a repair/replacement program for the system. Potential implications of pipeline conditions from an internal corrosion and water quality perspective are described in Section 4.

3.2.4 Flow reversals

Introduction of Doheny flows may result in reversal of flow direction within the transmission pipelines as follows:

- ***JTM:*** Flow direction would be reversed to the north of the expected tie-in location, while flow direction would remain the same to the south towards its terminus at Edison.
- ***WIP:*** The segment of the WIP pipeline from the interties between the JTM and WIP to the SCWD Zone 5B Reservoir to the north would flow in the same direction it currently flows, whereas flow to the south towards the TCPRS and the SCP would be reversed.

The flow reversals would result in higher HGLs in the JTM and WIP, which should be evaluated as part of the recommended hydraulic analysis described in Section 3.1.1.

Based upon the discussions in 3.2.1 and 3.2.2, it will be possible that there will be little to no impact on MET's system upstream of the Coastal Junction and TCPRS.

3.2.5 High/Low flow velocities

A significant increase in flow velocities within the JTM, WIP, and SCP in not anticipated. The WIP has the smallest current diameter of all the transmission pipelines that would be impacted by the Doheny facility at 27 inches. Assuming all 23 cfs generated by Doheny is delivered through this line, the maximum velocity would be 5.8 ft/s. The maximum potential velocities in the other, larger pipelines would be less.

The primary concern with low velocities is to minimize the potential for stagnation. At locations where water sources meet or there are dead ends due to low demand, there will be times and locations where the velocity of flow is zero and may result in stagnation. The recommended hydraulic model would be able to determine potential low velocity and water quality issues resulting from possible stagnation. Sedimentation, which can occur when water stagnates, is generally not a concern in potable water lines, but other water quality and operational concerns may arise. The implications of water age are discussed further in Section 3.3

3.2.6 Pipe pressure class incompatibility

The hydraulic model will provide updated data regarding the HGL at delivery points under various delivery scenarios. As discussed previously, in locations where the HGL increases, the ability of the transmission mains to operate under the new hydraulic conditions must be evaluated. In addition to evaluating the impacts to regional transmission pipelines, potential impacts to each water user should be evaluated at each turnout. In some cases, it may be possible that the new delivery pressure exceeds the design pressure class of the existing pipelines, and rehabilitation/replacement or installation of pressure reducing facilities may be necessary. *Recommendation: Utilizing updated HGLs at each turnout, identify turnouts with significant increases in delivery pressures and, in cooperation with water users, evaluated potential impacts to user facilities.*

3.3 Water age and implications

High water age in a distribution system can result in water quality degradation, which arises from disinfectant residual loss. In predominantly chloraminated systems such as most MWDOC member agencies, residual loss is driven by and concurrent with nitrification.

Nitrification is the oxidation of ammonia to nitrate with an intermediate step of nitrite formation (AWWA, M56). Ammonia-oxidizing bacteria (AOB) consume free ammonia and produce nitrite (Equation 1). Nitrite-oxidizing bacteria (NOB) further metabolize nitrite to form nitrate (Equation 2). In drinking water distribution systems, nitrite build up is commonly observed rather than conversion of the nitrite to nitrate unless nitrification is very severe.

AOB conversion of ammonia to nitrite:

$NH_3 + 1.5\ O_2 \rightarrow NO_2^- + H_2O + H^+$ *Equation 1*

NOB conversion of nitrite to nitrate:

$NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$ *Equation 2*

Monochloramine (NH_2Cl) formation:

$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$ *Equation 3*

The presence of AOB in water does not pose a serious public health risk due to the AOB themselves, but the generation of nitrite can seriously lower the disinfectant residual and pose a health risk by allowing bacterial regrowth. In addition, inadvertent metal release and corrosion may result in systems that are not well buffered due to decrease in pH, as shown by H^+ generation in Equation 1.

Free ammonia in drinking water distribution systems may be derived from the use of chloramines as a disinfectant residual. While chloramine disinfection provides better control of disinfection byproducts than chlorine, an unintended consequence can be an increase in the abundance of AOB, increasing the risk of nitrification in the distribution system. Chloramine is formed from the reaction of chlorine (e.g. Cl_2, HOCl) and ammonia (NH_3) as shown in Equation 3, optimally at a mass ratio of 5:1 chlorine-to-ammonia (reported as Cl_2:NH_3-N). This ratio is ideal for the preferential form of monochloramine species and the limitation of free ammonia. At ratios less than 5:1, free ammonia exists and can be available for AOB conversion to nitrite.

AOB survival is determined by several factors (AWWA, M56):

- **Temperature** - The optimal range is between 25 to 30 °C; however, nitrification can occur over a wide range of temperatures.

- **pH** – Similarly, nitrification can occur at a wide range of pH values. The reported optimal pH range is 7.5 to 8.5 standard units (S.U.).
- **Chlorine-to-ammonia ratio** – Ratios below the ideal ratio of 5:1 allow for the presence of free ammonia that can be used by AOB as an energy source.
- **Disinfectant concentration** – insufficient disinfectant residual can allow proliferation of bacteria.
- **Water age** – AOB are slow growing microorganisms, which is why strategies such as increasing turnover can be effective in controlling nitrification.

Distribution system modeling can be used to identify or predict:

- Water age
- Locations with high water age
- Opportunities for opening or closing valves to route flow in certain directions to minimize water age
- Nitrification potential
- Operational changes to reduce water age
- Possible improvements to water age by eliminating dead ends

While all distribution systems are unique and disinfectant decay will vary with parameters such as pipe material, temperature, concentrations of organic matter, and pH, as well as system operations, most systems will lose free chlorine residual in approximately 3 to 5 days. In comparison, chloraminated systems, due to the stability of the disinfectant, can maintain adequate residual for up to 10 days or longer. Distribution system modeling can help member agencies identify their water age goal by comparing predicted water age with historical water quality data.

Water age associated with loss of residual and nitrification episodes can be evaluated and used to compare possible changes in the distribution system for improvements. Using the model to test operations, flushing, and/or infrastructure improvements would enable them to reduce the number potential locations for residual loss and nitrification.

Maintaining the distribution system in a clean condition is critical for maintaining chloramine residual levels and avoiding nitrification. The primary maintenance activities for keeping the distribution system clean are distribution system flushing and reservoir (tank) cleaning. Routine flushing is an established practice for maintaining distribution system water quality but can be challenging during drought conditions. Dead-ends and other areas with long detention times are prone to nitrification incidents, particularly in the warmer summer and fall months. By reducing distribution system water age and removing sediments and biofilm, flushing may reduce the frequency of nitrification.

There are two types of distribution system flushing. Conventional flushing is conducted by opening one or more hydrants or blow-offs and is usually performed to react quickly to water quality problems. Conventional flushing may also be used as a preventative action to maintain distribution water quality. It does not include directing the flow with valves. Hydraulic modeling can optimize flushing locations and flow rates to minimize “wasted” water and prevent nitrification.

Unidirectional flushing (UDF) is a more effective approach for maintaining water quality and preventing nitrification. It is conducted in a systematic manner by directing the flow to the desired main from one direction by isolating particular sections of pipes. The goal is to achieve water velocities greater than 5 feet per second, which will result in pipe scouring and removal of biofilms that may contain AOB. Successful UDF requires careful planning of the order in which pipes are flushed, the hydrants that must be opened, and the valves that must be closed or opened. The key is to ensure that water entering the main being flushed flows from other sections that have already been cleaned. Hydraulic models can help develop UDF sequences. Having these flushing sequences documented can also help operators effectively address water quality complaints in localized areas.

Nitrifying bacteria are routinely found in sediments and biofilms of storage tanks. Water velocities in storage tanks are low, sometimes resulting in significant sediment. Tanks also can store water for long periods of time, which may affect water age in large parts of a distribution system. Turnover refers to how much of a tank’s volume is replaced with fresh water during each draining and filling cycle. Water levels usually fluctuate in the upper part of a tank because of diurnal demand variation (equalizing storage), and the lower portion is reserved for fires. Because many utilities reserve more storage for fires than is needed, water age is increased. Hydraulic models can be used to help identify distribution system operations that will create more tank turnover and help prevent nitrification in and around the storage tanks. Models can also be used to identify if and how lower volumes of water can be stored in the distribution system while maintaining equalizing and fire storage.

Distribution dead-ends are areas with high potential for nitrification due to low velocities and high water age. Hydraulic models can help test infrastructure improvements to eliminate dead ends, possible bleeding at dead-ends used at pressure zone boundaries, as well as flushing optimization at dead ends.

In sum, modeling to identify system area water age and to control water quality concerns like disinfectant residual stability and nitrification is recommended prior to integration of the new supply, which will change flow patterns.

3.4 Modeling necessary to meet MET’s/DDW’s requirements

MET maintains a hydraulic model of their entire system. That model does not include water age/water quality analyses, although the software under which it was developed does allow for this. Discussion with MET will be required to either utilize their model or support MET personnel in performing in-house modeling using their existing computer model of their system to determine potential steady state pressure, flow, and water quality effects the Doheny facility would have on their system. The model is in DHI’s (formerly the Danish Hydraulic Institute) Mike Urban water modeling software. Since flow would be coming from lines that are not part of their system, they would require all the piping and appurtenance information for these lines so they could include them in their model. For pressure surge modeling, they would require the assistance of an outside consultant as they do not have the expertise to perform such analyses.

The Division of Drinking Water (DDW) is likely to require an "influence model" to show where new water supplies will go in the existing system. A model such as the one prepared for Tampa can provide numerous analyses:

- Water age
- Water quality
- Operational control modeling as well as predictive modeling to help inform member agencies to help them manage their systems as different blends of supplies are delivered to them.

Recommendation: Perform "Influence Model" in accordance with DDW requirements.

3.5 Hydraulic impacts on existing facilities/local turnouts

Based on the information provided, there are the potential for 32 turnouts along the JTM and 4 turnouts on the WIP to be supplied flow from Doheny using the hydraulic philosophy discussed above. There is also the potential for valving at the Bradt and 5B reservoirs, the TCPRS, and future PRS at the Coastal Junction to be impacted by the Doheny facility. Half the turnouts on the JTM (north of the Bradt Reservoir) and all four turnouts on the WIP as well as the reservoirs and the TCPRS would be subjected to higher HGL elevations than what they are currently experiencing. *Recommendation: Perform detailed inventories at each turnout to ensure that the appurtenances are capable of handling the higher pressures associated with the Doheny facility. Utilize hydraulic model to determine pressure and flow settings at each turnout.*

4. Water Quality

As more water agencies plan for future alternative water supplies, strategies are needed to manage integration and mitigate adverse impacts. Interactions between distribution system materials and the water being transported through the system can influence corrosion of distribution system materials and changes in the microbiological environment. General water quality targets are maintained by water treatment plants so that potential negative impacts caused by corrosion or changes in microbiological environment can be avoided.

This section presents a review of the interactions between different distribution system materials and the chemistry of delivered water, with an emphasis on the introduction of desalinated water into the distribution system. This review is followed by discussion of water quality targets and corrosion issues experienced in full-scale desalination plants, strategies to minimize potential negative impacts of desalinated water, and testing approaches for answering outstanding questions.

The Lead and Copper Rule (LCR) requires systems to implement optimal corrosion control treatment (OCCT) to minimize lead and copper release to drinking water. In addition, health departments such as the Water Boards Division of Drinking Water (DDW) can require a desktop corrosion control study, increased tap sampling, or corrosion testing to evaluate potential corrosion impacts associated with changing water sources.

4.1 Changes in Water Quality with Introduction of Doheny

Desalinated ocean water must be stabilized before entering distribution systems. The removal of calcium and alkalinity by the reverse osmosis process used in desalination makes the water corrosive to many piping materials. Stabilization, or post-treatment, involves the addition of select minerals and other buffering constituents, including calcium and carbonate alkalinity in combination with pH adjustment to condition the water.

Post-treatment of desalinated water must consider the optimal water quality targets for a variety of distribution system and premise plumbing materials, while maintaining simultaneous compliance with regulations affecting the distribution system. Water quality targets can differ for controlling corrosion of iron, cementitious materials, lead, and copper materials. For this reason, it is critical for water systems to understand distribution system and premise plumbing materials of concern when introducing alternate water supplies so that a customized corrosion control strategy can be developed.

A literature search was conducted to summarize knowledge on corrosion impacts to common distribution system materials, focusing on impacts of desalinated ocean water supply, and identifying useful indicators or predictors of corrosion (corrosion indices).

4.1.1 Literature

4.1.1.1 Post-Treatment: Water Quality Targets and Indicators of Corrosion Potential

Post-treatment to increase the pH, alkalinity, and hardness can help to control corrosion of multiple distribution system materials. The stability of the finished water is often characterized with several indices that estimate the calcium carbonate saturation. Numerous indices exist for the characterization of water stability. Langelier Saturation Index (LSI) and calcium carbonate precipitation potential (CCPP) provide an estimate of the tendency of a water to form protective calcium carbonate scale on internal pipe surfaces versus the tendency to dissolve this scale. LSI is defined as the difference between the water’s pH and the saturation pH for calcium carbonate in the water. LSI is generally considered useful for assessing a water’s corrosivity when alkalinity is greater than 40 mg/L, sufficient dissolved calcium is present, and pH is between 6.5 and 9.5 S.U. CCPP provides a more quantitative and accurate measure of a water’s tendency to form calcium carbonate scale (Gebbie, 2000), but it is a more complex calculation that has limited its application in the past. However, CCPP has gained wider adoption with the American Water Works Association’s release of a spreadsheet program that simplifies the calculation process. Negative LSI or CCPP indicates that water is likely to dissolve calcium carbonate, while positive LSI or CCPP indicates that water is supersaturated with calcium carbonate (Rossum and Merrill, 1983; Gebbie, 2000). The AWWA Manual M58 includes a bench-scale calcium carbonate precipitation testing procedure that can be used to refine treatment targets to produce water quality conditions slightly supersaturated with calcium carbonate. A target CCPP range of 4 to 10 mg/L as $CaCO_3$ is often recommended for post-treatment of membrane permeate (AWWA, 2007); pipe loop testing showed that a CCPP greater than 0 mg/L was sufficient to minimize impacts to cement mortar lining such as a large pH increase and aluminum leaching (Blute et al., 2008). Stabilizing desalinated water produced through reverse osmosis to achieve satisfactory levels of CCPP can help to control corrosion of iron and cementitious materials in the distribution system.

Other indices, such as Larson ratio (LR), chloride-sulfate mass ratio (CSMR), aggressive index (AI), Ryznar stability index (RSI), and Riddick corrosion index (RCI) have been suggested in the literature. However, the usefulness of these indices is questionable. An expert panel convened by MET in October 2017 concluded that, with the exception of the Larson Ratio, these other indices have limited if any value for evaluating distribution system corrosion impacts. Instead, the panel suggested that the most important index was CCPP and recommended that gradual changes in water quality (pH, chloride, sulfate) be encouraged when integrating new water sources. However, it is important to understand that the CCPP index does not characterize the potential corrosion of lead or copper. The 2016 USEPA corrosion control treatment guidelines discourage the use of calcium carbonate-related indices such as CCPP and LSI to predict and evaluate lead and copper corrosion control (USEPA, 2016).

Table 4-1: Indicators of Corrosion Potential

Index	Target of indices	Materials for which the index may predict corrosive water
Langelier Saturation Index (LSI)	Supersaturation or undersaturation of calcium carbonate	Cementitious Materials
Calcium Carbonate Precipitation Potential (CCPP)	Supersaturation or undersaturation of calcium carbonate	Cementitious Materials
Larson Ratio (LR)	Accounts for chloride, sulfate and protective effect of bicarbonate	Iron-based Materials (additional confirmation needed from testing)

4.1.1.2 Corrosion of Cementitious Materials

Cement mortar linings are used as a method for prevention of corrosion and metals leaching from pipes used to deliver water. However, cement mortar lining can also be subject to degradation associated with water quality. To prevent leaching of the calcium hydroxide and aluminum components of cement mortar lining, sufficient alkalinity must be present in the water to allow for deposition of calcium carbonate on the surface and in the pore structure of the lining (AWWA and EES, 2002; Berend and Trouwborst, 1999). Degradation of cement mortar lining occurs in the presence of waters with a combination of low alkalinity, low levels of calcium, and/or lower pH (i.e., a negative LSI or CCPP) because these waters are aggressive to calcium carbonate.

If a water is corrosive toward cement mortar lining, increases in the bulk water pH, aluminum and calcium concentrations, and alkalinity can be observed (Douglas et al., 1996; Blute et al. 2008). This type of corrosion is typically exacerbated under low flow or stagnant conditions that allow for long contact times (Douglas et al., 1996). The corrosion index CCPP has been demonstrated in pipe loop tests to reflect stability of the water toward cement mortar lining, with negative CCPPs resulting in elevated pH and aluminum concentrations, and positive CCPPs yielding no change to the water quality (Blute et al. 2008).

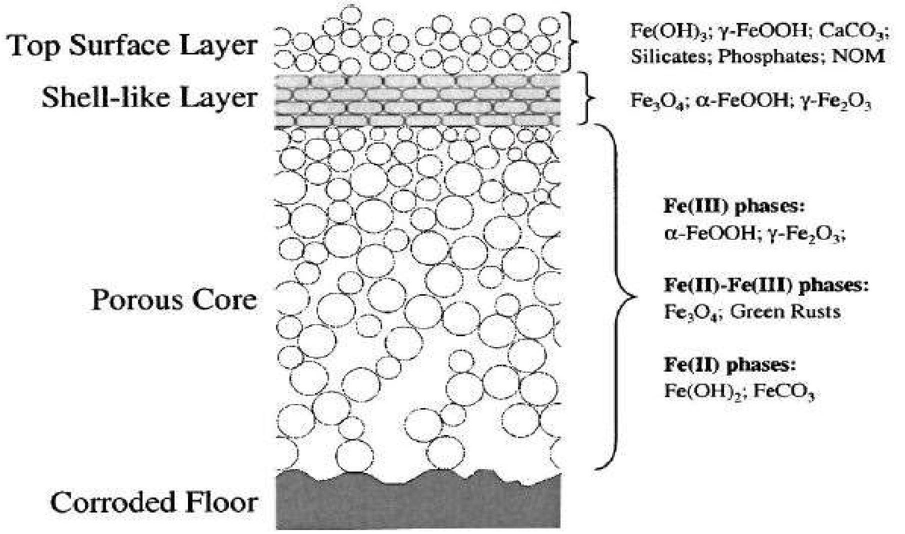
Desalinated water is low in alkalinity, calcium, and pH due to the rejection of cations and anions by the reverse osmosis membranes, requiring post-treatment stabilization (e.g., lime and pH adjustment). Adjusting the finished water quality through post-stabilization to achieve target ranges for CCPP and

LSI can significantly reduce the potential for leaching and degradation of cementitious materials in the distribution system.

4.1.1.3 Corrosion of Iron Pipe and Tuberculation

Corrosion of iron pipes presents a number of operational and aesthetic concerns. Operational concerns include potential for pipe leaks and water main breaks as well as tuberculation that can restrict the pipe's hydraulic capacity and increase pumping costs. Aesthetic concerns include potential for red or yellow water caused by release of corrosion byproducts. Corrosion byproducts include ferrous and ferric oxides that form multi-layered tuberculation on the interior of the pipes. The outer layer of tuberculation at the water-scale interface consists of a porous ferric oxyhydroxide layer that is relatively insoluble and maintained by the presence of an oxidant in the water. The outer tuberculation layer is followed by a shell-like inner layer and porous core that is in contact with the corroded pipe floor (Sarin et al., 2004) (Figure 4-1).

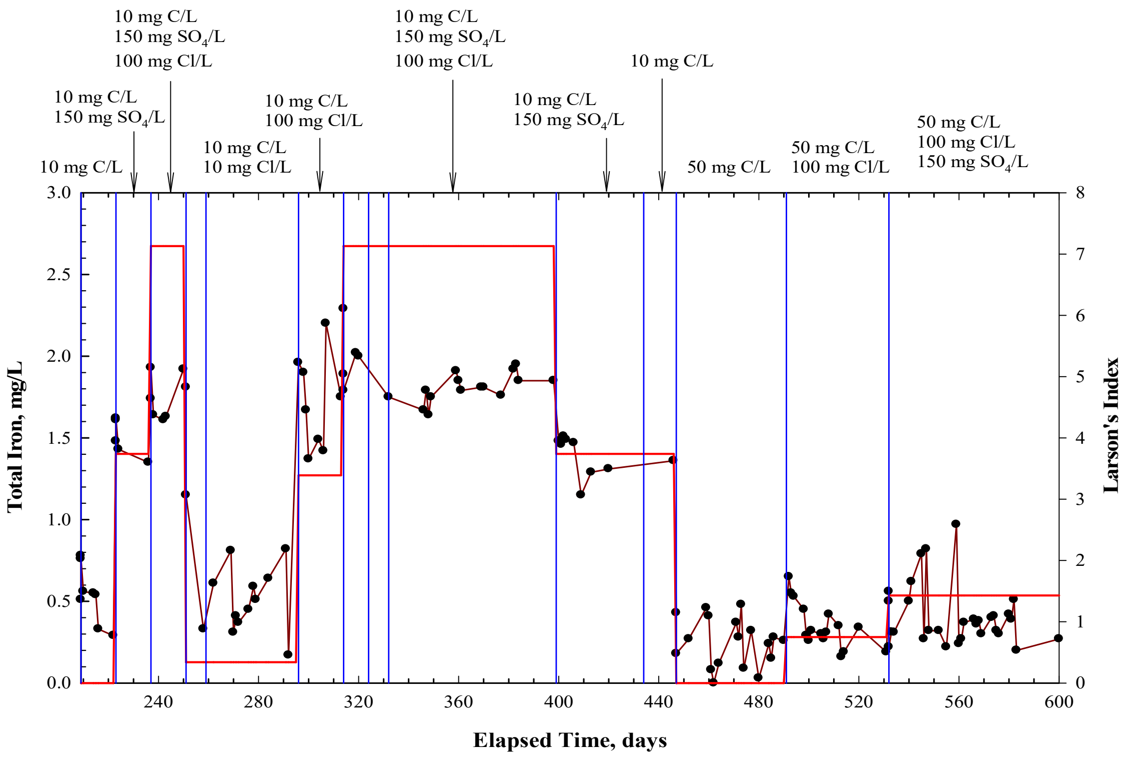
Figure 4-1: Scale Structure Inside Corroded Iron Pipe (Sarin et al., 2004)



Water quality parameters that affect iron corrosion include pH, alkalinity, dissolved oxygen (DO), disinfectant residual, sulfate, and chloride (Stumm, 1960; Pisigan and Singley, 1987; McNeill and Edwards, 1991; Raad et al., 1998; Kashinkunti et al., 1999; Sarin et al., 2003; Lytle et al., 2005; Lytle, 2017). Iron pipe corrosion and potential for red water are decreased when water alkalinity is high. The effects of higher pH on iron pipe corrosion can be opposing, with a decrease in corrosion byproduct release at higher pH but also increased pipe weight loss and tuberculation. Dissolved oxygen and disinfectant residual help minimize iron dissolution and stagnant conditions that deplete DO can result in red water (Benjamin et al. 1996). Increasing the alkalinity, either with sodium bicarbonate or lime/carbonate dioxide treatment, has been shown to control the release of iron corrosion products in the distribution system (Taylor et al., 2005).

Recent research has shown that significant increases in chloride and sulfate can result in iron releases from tuberculated pipe (Figure 4-2). The impact does not appear to be additive, and it can also be minimized by an increase in buffering capacity (alkalinity) in the water (Lytle et al., 2005; Lytle, 2017). The concept that absolute changes in chloride and sulfate impact iron corrosion, depending on the alkalinity present in the water, is supported by recent research (Lytle, 2017). This observation is relevant to integration of desalinated supplies, as chloride concentrations can increase over native supplies and alkalinities can be lower unless the water is adequately stabilized. Based on this work, the Larson Ratio was identified as a potentially useful indicator of conditions that promote iron release.

Figure 4-2: Research from Lytle (2017) showing the impact of chloride and sulfate on iron release with low and higher dissolved inorganic carbon (DIC)



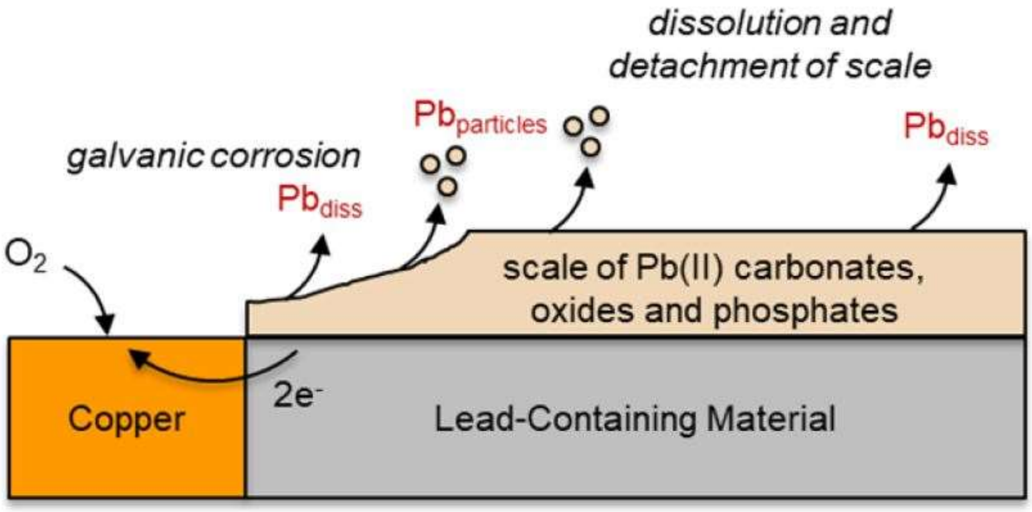
Additionally, galvanized iron pipe was used in many premise plumbing systems and is still present in buildings today. Systems in California have experienced impacts to galvanized iron pipe corrosion when changing water sources. For example, the City of Fresno experienced widespread water discoloration associated with galvanized iron pipe when changing from a groundwater to a surface water supply. Galvanized pipe materials have not been tested in pipe loops for Carlsbad or West Basin; hence, the presence of these pipes in a system planning integration of desalinated water should ensure that the post-treatment strategy is adequate to minimize scale disruption and discoloration of water. One strategy identified for addressing problematic galvanized pipe containing a large portion of iron surfaces contacting the water was the use of orthophosphate corrosion inhibitor (Tang et al., 2017). However, pilot studies are recommended to assess potential strategies for minimizing iron release from galvanized plumbing, the primary source of plumbing that caused red water issues in Tucson, Arizona, Flint, Michigan, and most recently, Fresno, California.

4.1.1.4 Corrosion of Lead Materials

Lead can enter tap water through corrosion of lead pipe as well as lead-containing solder and brass fixtures, although, lead-containing solder is considered the main source of lead in water for many situations (AWWA Research Foundation, 1996). Lead pipes and lead-containing solder were widely used in the U.S. before their use in new plumbing systems was banned in the 1986 Amendments to the Safe Drinking Water Act. The 1986 amendments specified that solder used in the distribution system must be composed of less than 0.2% lead., However, many existing systems still have pipes joined with lead-tin solder containing 50% lead. Even after the ban of lead-containing components in plumbing systems in 1986, fixtures with up to 8% lead were still considered lead-free until passage of the Reduction of Lead in Drinking Water Act in 2014. In Southern California, the primary source of lead to drinking water is solders and brass components, rather than lead pipe.

Mechanisms of Lead Passivation and Release. Corrosion of lead-containing plumbing materials occurs through reactions between dissolved oxygen, phosphate, or carbonate at the surface of the lead-containing material. Typical corrosion products on pipe surfaces include lead(II) carbonates and phosphates (Frenkel and Korshin, 1999; Schock, 1999) and lead(IV) oxide (PbO2(s)) scale (Edwards and Dudi, 2004; Kim and Herrera, 2010; Lytle and Schock, 2005; Ng et al., 2012; Schock et al., 2005; Triantafyllidou et al., 2015). Some scales that protect or "passivate" the lead pipe surface from further corrosion. However, these lead-containing scales can enter the water under the conditions of galvanic corrosion, a corrosion mechanism that occurs when two dissimilar metals are brought into contact with each other (Figure 4-3). In plumbing systems containing copper pipe sections joined with lead-tin solder, copper serves as the cathode and lead serves as the anode in the galvanic cell that drives corrosion (Arnold et al., 2011; Crittenden et al., 2012). Galvanic corrosion of the lead joining copper pipe results in areas of locally low pH that facilitate dissolution and detachment of the lead scales (Nguyen et al., 2010; Schock and Lytle, 2011).

Figure 4-3: Formation of lead-containing scale, galvanic corrosion, and dissolution of scale into solution (Giammar, 2018)



Water Quality Impacts on Lead Corrosion. Changes in water quality that occur when blending water sources or altering water treatment processes can have a significant impact on corrosion rates of lead-containing plumbing materials. Galvanic corrosion of lead-containing materials is more widespread across the surface of the anodic material when the surface is exposed to high conductivity waters, and high conductivity can also exacerbate overall lead release. The solubility and dissolution of lead-containing plumbing materials is a strong function of pH (Schock and Lytle, 2011) and pH below 8 S.U. has been associated with increased lead leaching from lead-tin solder (Lee et al., 1989). Alkalinity is known to play an important role in corrosion (Lee et al., 1989) and the locally low pH that occurs at the material surface during galvanic corrosion will be more extreme with lower alkalinity waters (Nguyen et al, 2010). Orthophosphate corrosion inhibitors can be used for lead corrosion control and are most effective for lead in the pH range of 7.2 to 7.8 S.U. (Dodrill et al, 1995; Cantor et al, 2000; McNeill et al, 2002). Orthophosphate is not effective for lead corrosion control at higher pH levels.

In the absence of orthophosphate, increasing the pH decreases the lead solubility (up to a pH of approximately 9.7 S.U.) and results in lower lead release to drinking water. In general, lead solubility is more sensitive to pH than alkalinity and dissolved inorganic carbon (DIC). At pH levels in the range of approximately 7 to 8 S.U., higher alkalinity and DIC levels reduce the theoretical lead solubility and is beneficial for lead corrosion control. At pH levels greater than approximately 8 S.U., higher alkalinity/DIC levels can increase the theoretical lead solubility and increase lead release (Schock, 1989). Low levels of alkalinity and DIC (e.g. DIC below about 5 mg/L as C) can increase lead release (Edwards et al, 1999; USEPA, 2016).

In sum, systems introducing desalinated water into distribution should select pH and alkalinity targets that achieve positive CCPP to reduce iron release while providing protection against lead leaching and degradation of cement mortar-lined pipe. Increasing the finished water pH (e.g. pH >8 S.U.) will improve lead corrosion control. At these pH levels, higher alkalinity levels can increase the theoretical lead solubility, but sufficient alkalinity must be present to maintain distribution system buffering and counteract potential impacts of high chloride and low sulfate levels at low alkalinity levels. Sudden distribution system water quality changes can impact the stability of lead corrosion scales present on aged premise plumbing materials such as leaded solder and leaded brass. As discussed earlier, gradual change and appropriate water quality stabilization offer solutions to minimize lead leaching in this application. Maintaining a consistent pH throughout the distribution system is also critical for corrosion control, as fluctuating pH can lead to corrosion problems in isolated parts of the distribution system.

4.1.1.5 Corrosion of Copper Plumbing

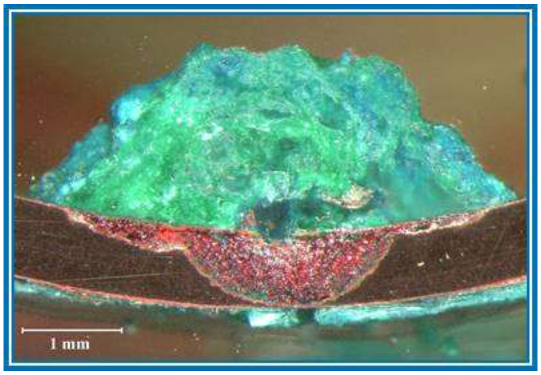
Copper pipe is the commonly used in premise plumbing systems (i.e., end-user plumbing). Corrosion of copper pipe can take the form of uniform (generalized) corrosion or non-uniform pitting corrosion. Pitting corrosion can cause pinhole leaks leading to premature failures of copper pipe. Uniform corrosion leads to release of copper to water that can cause aesthetic concerns (e.g., blue staining and blue ice cubes), LCR compliance impacts, or health effects at high concentrations.

The corrosion of copper pipe results in the conversion of metallic copper into cuprous or cupric forms that can become solubilized or form a precipitate, depending on water chemistry. While many water quality parameters influence copper corrosion, alkalinity and pH are the most highly correlated to copper corrosion (Xiao et al., 2007). Because most copper compounds become soluble below pH of 6 S.U., uniform copper corrosion can occur at low pH while high pH decreases copper solubility (Schock et al., 1995; Dodrill et al., 1995; Edwards et al., 1996; Brown et al., 2013). In contrast to lead corrosion, copper corrosion is increased in higher alkalinity waters because copper forms soluble complexes with bicarbonate (Dodrill et al., 1995). The negative impacts of high alkalinity copper corrosion are exacerbated at low pH levels.

Cation and anion levels also affect copper corrosion rates. High levels of chloride can initially be aggressive to copper but eventually lead to formation of a scale that prevents further corrosion. High levels of sulfate are initially less aggressive to copper but can lead to the formation of a scale that promotes copper corrosion over time.

The water quality conditions that promote copper release to drinking water (e.g. low pH and high alkalinity) differ from the conditions that promote copper pitting. High hardness in groundwaters has been associated with cold-water pitting corrosion in many systems in California (Edwards et al., 1999). Copper pitting is also known to occur in water with high pH, low alkalinity, low conductivity/TDS, and no orthophosphate, and this pitting can be further accelerated in the presence of even relatively low levels of natural organic matter (NOM) (Sarver et al, 2012). Addition of an orthophosphate-based corrosion inhibitor can be effective for preventing copper pitting corrosion (Lytle et al, 2018).

Figure 4-4: Image of Copper Pit Formation, comprised of Cu(II) sulfate or Cr(II) chloride minerals (Lytle, 2019)



NOM been found to be strongly associated with copper corrosion because it prevents the formation of low-solubility scale such as malachite or tenorite (Edwards et al., 2001; Li et al., 2004; Arnold et al. 2012). Edwards et al. (1999) reported that water color associated with NOM was detected at the majority of utilities exceeding the copper action level. High levels of NOM have also been implicated in reducing the effectiveness of orthophosphate corrosion inhibitor (Li et al., 2004), which can negatively impact both copper and lead corrosion control.

Stabilization of desalinated water to increase the pH will significantly reduce the release of copper to drinking water. Increasing the alkalinity with post-treatment will technically increase copper solubility, but moderate levels of alkalinity are necessary to maintain distribution system buffering and maintain a consistent pH in the distribution system for corrosion control. Desalinated water with low alkalinity and high pH may present a risk for copper pitting, especially due to the low levels of NOM in desalinated water treated with reverse osmosis. While the presence of NOM can increase uniform copper corrosion, low NOM in a low alkalinity, high pH water can increase copper pitting. Stabilization of desalinated water to increase pH and alkalinity for a positive CCPP (without too high of a pH value) can be beneficial for reducing the potential for copper pitting corrosion.

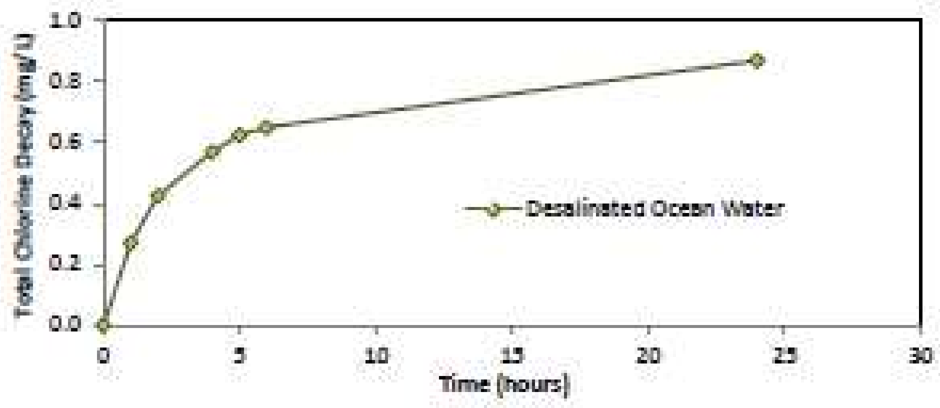
4.1.1.6 Disinfectant Stability and DBPs in Desalinated Water

Integration of desalinated water can also introduce issues associated with bromide. Bromide can be present in seawater in high concentrations (~80 mg/L in some areas), and some of this bromide can pass through the water treatment process (World Health Organization, 2011) and be present in permeate. In the presence of bromide, monochloramine decomposition is greatly accelerated (Vallentine and Selleck, 1982). The decay process occurs by either direct substitution of bromine into chloramine or by formation of hypobromous acid that reacts with ammonia; both of these methods result in formation of bromamine (Pope et al., 2006; Vikesland et al., 2001). Bromamine is much more reactive than chloramine and quickly decays to bromide and ammonia because it is very unstable. Bromide in permeate at levels of 0.1 mg/l did not significantly affect monochloramine decay rates; however, increasing levels to 0.5 mg/L and greater accelerated monochloramine decay rates (Vallentine, 1998).

Most desalination treatment plants target bromide concentrations that are lower than 0.5 mg/L. For example, the Tampa Bay Water (TBW) Desalination project has contract limits of 0.450 mg/L of bromide. The Carlsbad Desalination Project has contract limits of 0.4 mg/L as a central tendency, which cannot exceed 0.7 mg/L in more than 10 percent of the samples collected. The TBW project experienced chloramine stability challenges early in its implementation which were mitigated by blending with other regional water sources. The Carlsbad project has reported that it has not observed chloramine stability challenges (WRF Desal 15-06).

In work at West Basin, testing conducted by MET using desalinated water and blends found that chloramine decay for two different bromide values (0.25 mg/L and 0.49 mg/L) was similar in laboratory tests. Results of this work yielded the chlorine demand curve for desalinated water (Figure 4-5). Based on this work, 5 hours of contact time in a clearwell was identified as a strategy to minimize impacts from initial chloramine degradation, after which chlorine can be boosted before entering the distribution system.

Figure 4-5: Chloramine decay measured in desalinated ocean water (Scott and Tirtadidjaja, 2014)



While disinfection byproducts (DBPs) are generally low when disinfection occurs on RO permeate (Scott and Tirtadidjaja, 2014), pre-membrane chlorination such as to control biofouling can result in high DBPs. TBW experienced this challenge, and found that the TTHMs were primarily brominated species (Owen, 2019). Consideration should be given to potential DBPs and impacts of bromide on chloramine stability in planning for integration of Doheny. Because brominated THM species are likely candidates for future regulation, future studies should include brominated THM formation in the blends of desalinated water and treated water from the Diemer plant.

4.1.1.7 Summary of Key Water Quality Issues that Impact Desalinated Water Integration from the Literature

In summary, research has illustrated key factors that impact corrosion of pipes and pipe deposits. Some of the factors are counter to each other and need to be balanced for effective integration of a new supply. For example, sufficiently high pH and adequate alkalinity provides protection of cement mortar lining and lead materials. Too high of a pH can result in copper pitting if treated water alkalinity is low.

As with all materials, the potential for release of metals from pipes depends on the nature of the deposits/tuberculation. Iron release has been shown to increase when chloride or sulfate significantly release, particularly when alkalinity is not sufficiently high to minimize impacts.

Finally, chloramine stability in desalinated water supplies can be impacted by elevated bromide levels, which can form bromamine intermediaries that are less stable, but research shows that impact can be overcome. Subsequent sections focus on potential strategies to minimize corrosion and disinfectant residual stability when a new desalinated water source is introduced.

4.1.2 Experience with Desalination Treatment Plants

A limited survey of ten desalination plants throughout the world was conducted by West Basin Municipal Water District to assess corrosion issues and water quality targets with regard to alkalinity, calcium, CCPP, LSI, pH, boron, bromide, TDS, and chloride (West Basin, 2014). Only one facility reported corrosion issues - the Town of Jupiter, which experienced widespread corrosion issues in the past, mostly on copper and brass. To address their issues with corrosion, the system operators implemented a strategy of blending their finished water with nanofiltration permeate and using a corrosion inhibitor. Corrosion issues were either specifically not experienced in the other systems, or corrosion problems were not reported [e.g., TBW (Owen, 2019)]. Corrosion issues may have been avoided in many systems because of the stabilization methods used to achieve finished water quality that is not corrosive to the components of the associated distribution system. Corrosion issues were likely able to be avoided in many of the systems surveyed because of their choice of appropriate water quality targets that allow the water to be non-corrosive to the distribution system materials.

Most facilities in the survey targeted alkalinity and calcium concentrations between 50 and 100 mg/L as $CaCO_3$. Target pH values ranged from between 7.3 and 8.5 S.U., and CCPP and LSI values were positive. Reported water quality targets were achieved partly through implementation of stabilization strategies including pH, calcium, and alkalinity adjustment and through blending strategies. Stabilization strategies included lime (with CO_2 or sulfuric acid) or calcite filters to increase the calcium concentration. Lime plus CO_2 and calcite filters offer the benefit of additional alkalinity compared with use of sulfuric acid.

4.2 Potential changes with future DPR

Future direct potable reuse may come in the form of either raw water augmentation (the potable reuse water is directed to the head of a drinking water treatment plant), or treated water augmentation (i.e., directly to distribution). In the case of the former, blending and treatment at the water treatment plant will need to be managed to achieve suitable water stability of the final drinking water product prior to distribution. For the latter, specific attention to stability indices will be required.

Future direct potable reuse (DPR) for treated water augmentation will share the corrosion and integration related challenges as desalination due to the use of reverse osmosis. With a very similar water quality produced with low alkalinity, hardness and pH, the requirements for post treatment and stabilization are essentially the same. One consideration is that chloramine is commonly used to control biological fouling in the RO membranes, and will persist into the final RO permeate. This may be at levels of 2 mg/L to 4 mg/L as Cl_2 and control/quenching strategies may be required when blending into the distribution system.

Unlike other states which are considering non-RO systems, California is most likely to use RO based treatment for DPR almost exclusively. In the unlikely case that adsorption methods are utilized (such as ozone/BAC/GAC) the water quality will likely contain higher levels of TDS, hardness, alkalinity and TOC.

4.3 Strategies/tools to minimize change

Corrosion control in water systems is managed through formation of stable scales that both reduce the rate of corrosion and have a very low tendency to release metal ions that would result from corrosion. Several options, including stabilization and blending, are described in more detail as follows.

4.3.1 Stabilization

Desalinated water supplies require the addition of calcium and alkalinity, and pH adjustment. Post-treatment processes identified in the literature review and survey for desalinated ocean water stabilization include addition of lime (calcium hydroxide, $Ca(OH)_2$), often with carbon dioxide (CO_2) or sulfuric acid) or use of a calcite contactor. pH adjustment with caustic may also be used to achieve final treated water quality targets.

Potential water quality stabilization techniques for corrosion control are provided in Table 4-2. A compilation of the primary observations from the literature described previously is included, as well as the corrosion indices that are reflective of the stabilization techniques.

Corrosion inhibitor is listed as a potential stabilization technique because it is identified in the Lead and Copper Rule as a strategy in addition to the other techniques. However, most desalination plants use post-treatment pH, alkalinity, and calcium adjustment for corrosion control rather than corrosion inhibitors.

Table 4-2: Stabilization Techniques for Corrosion Control

Stabilization techniques	Observations related to corrosion impacts	Corrosion indices reflective of the technique
pH adjustment	Sufficiently high pH contributes to water quality that is stable for cement mortar lining Higher pH (>8 S.U.) minimizes lead and copper release in the absence of orthophosphate (with orthophosphate, the benefit of the corrosion inhibitor is less at pH > 7.8 S.U.) Unstable pH has been associated with iron release	CCPP, LSI
Alkalinity adjustment	Sufficiently high alkalinity contributes to water quality that is stable for cement mortar lining Moderate alkalinity is needed to avoid copper pitting that can occur at elevated pH and low alkalinity Moderate to high alkalinity can stabilize iron release even when chloride and sulfate concentrations rapidly change	CCPP, LSI, LR
Calcium hardness adjustment	Sufficiently high calcium contributes to water quality that is stable for cement mortar lining	CCPP, LSI
Corrosion inhibitor	Effectiveness dependent on inhibitor concentration, pH (optimal 7.2 to 7.8 S.U.), DIC, and other constituents	None

4.3.2 Blending

Blending of alternative water supplies into the distribution system can affect corrosion potential. The blending approach and resulting changes in water quality can minimize or increase corrosion issues depending upon the approach taken. Past research on blending includes: Stanford et al. (2016) showing that sudden loss of a DPR supply could significantly impact water quality; Taylor et al. (2005) evaluating impacts of blending the historical groundwater source with a new surface water source for Tampa Bay Water; Blute et al. (2008) conducting pipe loop corrosion tests of a new desalinated water supply; Duranceau et al. (2011) evaluating blending strategies for a desalinated water supply; and Dewis et al. (2010) identifying mitigation strategies. Prior research has evaluated the operational factors associated with blending of distinct source waters but often has not considered temporal changes in the blending ratio, such as seasonal changes in blending due to water supply, daily changes due to operational and hydraulic factors, and abrupt source changes.

Gradual changes in water quality, such as those practiced by MET in blending State Project water and Colorado River water, have been shown to be effective at minimizing corrosion issues. By comparison, recent abrupt changes from groundwater to MET water have resulted in corrosion issues for several agencies, including Sierra Madre and South Pasadena.

4.3.3 Disinfectant Residual Stability

Three relatively recent studies (Pope and Musullam, 2013; Erdal and Lozier, 2013; West Basin, 2014) report chloramines were more stable at a higher pH (e.g., 8.2 S.U.) in desalinated ocean water. In the alternative approach tested, pH was adjusted to 8.2 ± 0.2 S.U. first, followed by a chlorine dose with mixing, then an ammonia dose with mixing.

In a bench testing of desalinated water with pH adjustment followed by chloramination, total chlorine degradation occurred mostly in the first 4 to 5 hours after ammonia addition (Scott and Tirtadidjaja, 2014). Afterwards, total chlorine appeared to be relatively stable. By comparison, chloramination prepared by the other approach (chloramination followed by pH adjustment) appeared to be less stable.

The finding in this study provides a data point for determination of clearwell detention time. With a 4 to 5-hour detention time, bromamine reactions can occur, and the total chlorine residual can be trimmed on the effluent from the clearwell as the water flows to the distribution system.

4.4 Testing approaches for outstanding questions

A variety of corrosion testing approaches have been used by utilities and published in the literature. Several corrosion testing approaches were developed in the 1990s and focused on pilot-scale pipe loop studies, which present significant cost and complexity to implement. Industry practitioners and academic researchers have developed various bench-scale testing approaches to evaluate lead and copper release, and such methods have been utilized in numerous research applications that have expanded the industry's understanding of corrosion mechanisms. However, a lack of standardization and general consensus on testing protocols has hindered broader use of bench-scale testing approaches by utilities, and a significant need remains in the water industry for an effective, proven bench-scale testing approach with widespread applicability.

4.4.1 Scope

A variety of different testing approaches have been utilized in prior corrosion control studies and research efforts. This section provides an overview of the corrosion testing strategies summarized in Table 4-3. The effort can start with a desktop study to define the testing objectives and approach.

Desktop Study. The first step in planning for desalinated water integration involves identification of the components that should be considered, including:

- Water quality in the current distribution system
- Piping materials and appurtenances in the distribution system that will be receiving the water
- Degree of tuberculation in pipelines
- Post-treatment water quality targets

A water quality analysis forms the basis for the desktop corrosion control study. It is important to evaluate water quality in the distribution system to identify water quality extremes that could impact corrosion and to consider how changes to distribution system operations and maintenance could affect water quality.

Materials evaluation should include a review of existing materials evaluation records and operations observations of tuberculation during pipeline replacements or repairs. Systems should also identify common distribution system main materials which could be affected by water quality and treatment changes, such as unlined cast iron pipe, cement-lined pipe, and concrete pipe. The predominant (and range of) household plumbing materials should also be identified.

The following strategies are additional tools which can be performed as part of a desktop study to enhance the results:

- **Water quality models** – Several spreadsheet-based models are available to evaluate bulk water quality parameters, calcium carbonate scaling characteristics, and impacts of chemical addition on pH, alkalinity, and calcium saturation. Model platforms include the Rothberg, Tamburini, and Winsor (RTW) model, the Trussell Tech model, and the Water!Pro model. These models are particularly useful to estimate the chemical doses needed to achieve target pH and alkalinity values for corrosion control. In addition, these models can also be used to evaluate the potential for changes to distribution system scaling due to source water or treatment chances.
- **Scale Analysis** – Scale analysis can be a useful tool to understand mechanisms of corrosion control and potential corrosion impacts associated with changing water sources. This approach requires harvesting of pipe samples from the system for laboratory analysis. Scale analysis often includes analyses such as X-ray diffraction and scanning electron microscopy to determine the elemental composition and mineral species present in the scale.
- **Solubility models** – Several metals solubility models, such as MINEQL, can be used to estimate the equilibrium solubility of lead and copper scales under different water quality conditions. These models can provide useful information for screening the theoretical effects of corrosion control treatment alternatives or other treatment changes. However, these models do not account for important aspects of kinetics, galvanic corrosion, and particulate lead release and should not be a substitute for corrosion testing.
- **Review of analogous systems** – A systematic review of effective corrosion control treatment techniques utilized in other water systems with similar characteristics, including

source water, treatment, and water quality, can provide insight on corrosion control strategies proven to be effective in similar situations.

Corrosion Testing Methods. Following the desktop studies, further testing can be identified and undertaken utilizing one of the methods summarized in Table 4-3.

Table 4-3: Summary of Corrosion Testing Strategies

Method	Best Applications	Potential Drawbacks
Coupon Testing	• Overall corrosion rate; • Monitoring of infrastructure degradation	• Does not monitor metal release to drinking water; • Does not include representative materials; • Not recommended for LCR compliance purposes
Immersion Testing	• Screening of strategies for reducing metals release; • Understanding corrosion mechanisms	• Does not consider the effects of flow; • New materials (not representative of distribution system scales); • Not suited for testing of lead service lines, cast iron mains, or copper pitting
Recirculation Pipe Loop	• Testing corrosion control with batches of test water in flowing conditions; • Can use harvested materials; • Can perform scale analysis	• Challenges in sample collection; • Water quality changes in recirculation reservoir
Flow-Through Pipe Loop	• Pilot-scale demonstration testing of corrosion control strategies; • Can use harvested materials; • Can perform scale analysis; • Long-term monitoring	• Complex and costly to implement; • Large footprint; • Challenges in operation and maintenance;

Coupon Weight Loss Testing. Conventional coupon testing involves a flat, rectangular sample of metal (known as a "coupon") placed in a flowing pipe rack, often located at a water treatment plant or at key locations in the distribution system. Coupon materials often include pure lead, copper, and steel, and coupons are manufactured to specific size and weight standards for testing. Coupons are periodically removed from the loop, cleaned to remove accumulated corrosion byproducts, and weighed to monitor weight loss in the coupon, which provides an indication of the overall corrosion rate. Coupon weight loss testing originated for industrial applications to monitor the corrosion and degradation of process equipment and system materials. In some cases, utilities have utilized coupon weight loss techniques to monitor the overall corrosivity of finished water over time.

The coupon weight loss testing approach presents significant limitations and drawbacks for use in evaluating lead and copper release to drinking water. Existing corrosion control guidance cautions against the use of coupon weight loss testing for evaluating lead and copper release to drinking water (Schock, 1999; OMOE, 2009; USEPA, 2016). For example, AWWA guidance describes that "traditional coupon studies are unlikely to be informative when a utility is evaluating the potential effect of changes on CCT" (AWWA, 2005).

This method does not include provisions for measuring metals release to drinking water, which is of paramount importance for LCR compliance and public health. Weight loss provides an indication of the overall corrosion rate, which is not necessarily proportional to metal release to drinking water. Coupon often incorporates pure lead coupons, which are not necessarily representative of aged lead service lines in the distribution system with existing corrosion scale layers. Coupon testing is not suitable for monitoring localized corrosion process such as galvanic corrosion or pitting, which can be significant factors affecting corrosion in drinking water systems. Coupon weight loss testing is also not recommended for LCR compliance purposes. We do not recommend this approach for testing water quality implications of a new water supply.

Immersion Testing. Immersion testing is a bench-scale strategy that has been widely utilized in lead and copper corrosion studies, including academic research and practical utility studies for LCR compliance. Immersion testing is not intended to predict the lead and copper concentrations at the tap but rather to identify effective treatment alternatives (Medlar et al, 1994). Industry guidance indicates that immersion testing is suitable for evaluation and initial screening of corrosion control treatment strategies (Schock, 1999; AWWA and DVGW, 1996). One study described that “bench-scale immersion tests can be a useful tool for bridging the academic desktop studies and the more expensive loop demonstration testing” (Medlar et al, 1994).

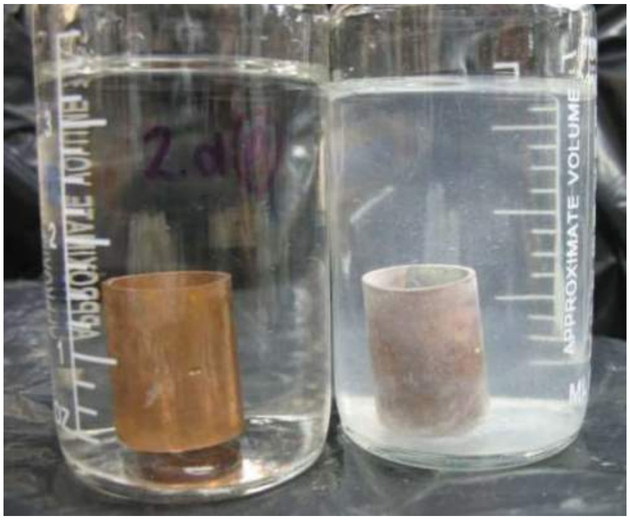
Immersion testing has been used to evaluate corrosion mechanisms and optimal corrosion control treatment (USEPA, 1993; Kirmeyer, 2004). Immersion testing has also been used to screen multiple corrosion control treatment alternatives to narrow the quantity of test conditions for subsequent pipe loop testing (Kirmeyer et al, 2004; Roth et al, 2017). Immersion testing is intended to measure relative differences in corrosion and metals between test conditions. For example, utilities can use corrosion testing to evaluate if a treatment change is expected to increase, decrease, or not affect corrosion in the system but not to determine the specific amount of the change in the distribution system (Parks et al, 2014).

A variety of immersion methods have been utilized, and there has been little standardization between studies. This method has sometimes also been referred to as coupon testing, static testing, or bench-scale testing, and is defined as “immersion testing” for purposes of this protocol to distinguish the method from traditional coupon weight loss testing.

Immersion testing involves subjecting metal samples to specific test waters and measuring the concentration of lead or copper released to the test water. Samples are held in stagnant conditions, and the test water is changed at a consistent frequency. Immersion testing can be conducted with one of the following methods (EPA, 1993):

- **Jar Testing** – A metal sample is placed into a glass jar and filled with test water. Figure 4-6 illustrates a jar immersion testing approach for copper pipe with leaded solder.
- **Pipe Sections** – A section of copper pipe, including leaded solder or brass samples, is plugged with silicone stoppers on both ends and filled with test water.

Figure 4-6: Example of Jar Immersion Testing Approach (from Nguyen et al, 2011)



Immersion testing is conducted in stagnant conditions, which create the greatest potential for metals release, and does not incorporate the effects of flow. Immersion testing allows test materials to be selected that are similar to sources of lead release in plumbing systems, including leaded solder and leaded brass, and can incorporate galvanic corrosion. Immersion testing typically uses new materials, which may not fully reflect existing scales in the distribution system, but use of new copper, solder, and brass materials are generally regarded to accurately reflect corrosion of existing materials in the distribution system. Immersion testing is not suited for testing of copper pitting, which requires flowing conditions, tuberculated iron mains, or lead service lines, for which the stability of existing scale layers is a critical factor in overall lead release.

Industry guidance indicates that immersion testing durations have generally ranged from 1-3 months (AWWA and DVGW, 1996; Kirmeyer, 2004), which is considerably a lower duration compared to pipe loop testing which can often last from 9 months to 2 years (USEPA, 1992; Parks et al, 2014, USEPA 2016). One study presenting the results from six immersion testing utility case studies concluded that “the performance of the various additives is relative one to the other almost from the beginning of the test and eventually become asymptotic… Abbreviated test periods of, say, less than 2 months can comfortably be used to compare alternative treatment schemes” (Medlar et al, 1994). Metals release is typically high when new metal samples are exposed to test water and rapidly decreases rapidly during initial testing (Kirmeyer, 1994).

Immersion testing water changes are often performed three times per week, resulting in stagnation periods of 48 to 72 hours (Edwards et al, 2007; Bradley, 2018; Tang et al, 2018). These extended stagnation times during immersion testing are representative of long stagnation times which can occur in premise plumbing systems during unoccupied periods, which are detrimental to lead release (Nguyen et al, 2011). Weekly composite samples are often collected for each test specimen (Edwards et al, 2007; Nguyen et al, 2011; Bradley, 2018).

Pipe Loop Testing. Pipe loop testing is a pilot-scale strategy that incorporates sections of lead and copper pipe materials into a flowing loop apparatus to simulate conditions in a premise plumbing system. Each pipe section is connected to a flowing supply of test water during operation. A pipe loop system typically includes a timer to alternate between flowing and stagnant conditions and a flow meter to monitor and adjust the flow rate of water through the pipe sections. Pipe loop testing can incorporate sections of harvested pipes to evaluate the stability of existing scale layers, and a conditioning period is needed to re-stabilize harvested pipes in the pipe loop. Pipe loop systems typically necessitate significant complexity, physical space, and cost to implement, and they incorporate electrical, instrumentation, and controls components. Pipe loops may need to be operated for months to years to stabilize harvested distribution system materials or develop representative scales (Kirmeyer, 1994; AWWA and DVGW, 1996; Blute et al., 2008; USEPA, 2016). Desalinated water integration testing at West Basin, Carlsbad, and Long Beach found that approximately 2 months was necessary for stabilization of harvested and new pipes, and that four or more months of testing was sufficient for basic testing of changing water conditions on multiple pipe types (Blute et al., 2008; Zhang et al., 2012).

Two general types of pipe loop systems include recirculation pipe loops and flow-through pipe loops, which are described as follows:

- **Recirculation Pipe Loop** – In a recirculating pipe loop, batches of test water are prepared and used to fill a reservoir, from which water is pumped through the pipe section according to a pre-determined schedule. The concentration of metals released from the pipe sections accumulates in the reservoir during recirculation. The test water in the reservoir is regularly replaced, and the water quality in the reservoir may vary during recirculation cycles. The accumulation of lead and copper concentrations in the reservoir can create challenges in sample collection and monitoring. A recirculation pipe loop is best used when test water must be prepared using a batch process instead of on a continuous basis.

Figure 4-7: Example of Recirculation Pipe Loop System

- **Flow-Through Pipe Loop** – In a flow through pipe loop system, each set of pipe sections is connected to a continuous supply of test water. To test alternate corrosion control treatment strategies, a pilot-scale chemical feed system is needed for each loop to adjust pH/alkalinity or add a corrosion inhibitor. Each loop includes a sample port to collect samples of the water inside the pipe during the stagnation period. The conventional flow-through pipe loop apparatus is based on the AWWA Research Foundation design (AWWARF, 1994), with subsequent modifications for addition of harvested lead service lines in some systems (AWWA, 2005). Additional Water Research Foundation work developed an alternate flow-through pipe loop systems known as a Corrosion Evaluation Rig that consisted of leaded solder and copper pipe, brass rod inserts, and lead pipe galvanically connected to copper pipe (Parks et al, 2014). Pipe loop approaches have been implemented by utilities with future desalination plants including Carlsbad (upon which the post-treatment stabilization approach was based; Blute et al., 2008) and West Basin.

Figure 4-8: Example of Flow-Through Pipe Loop System

4.4.2 Approximate cost of testing

For high-level project planning purposes, ranges of costs for immersion testing and pipe loop tests are provided in Table 4-4. Testing costs will vary depending on the study objectives, the type of materials, and the quantity of test waters. Staffing costs will vary depending on the type of personnel, staff qualifications, staff familiarity with the testing process, and the extent of laboratory/pilot-scale treatment requirements.

While bench-scale immersion testing can provide a relative indication of impacts to metals release and is useful for concept screening, it does not provide the capability to examine impacts to harvested distribution system materials. For introduction of a desalinated water into the distribution system, a pipe loop system provides an opportunity to incorporate harvested materials from the distribution system and premise plumbing systems to evaluate impacts to existing corrosion scales present in the system. Testing of new materials, such as cement-mortar lined pipe may not be needed unless a CCPP value lower than 0 mg/L is intended to be targeted, since this has not been thoroughly studied to date. Discussions should also be held with stakeholders (e.g., MET, member agencies, and DDW) to determine testing requested by other parties prior to permitting and introduction of the new source.

Table 4-4: Typical Costs for Testing Approaches

Method	Application	Approximate Cost of Testing
Coupon Testing	Not recommended for testing metal release	Not applicable
Immersion Testing	Evaluation of new materials	$50-100k
Recirculation and Flow-Through Pipe Loops	Analysis of existing scale from harvested pipes or appurtenances	$200-500k
Bench Testing of Chloramine Residual Stabilization	Clearwell sizing and booster chlorination design criteria	$20-30k

4.4.3 Expected outcomes

Based on this literature summary and discussion of potential testing approaches, the following are identified as best practices for consideration by MWDOC and member agencies when integrating a new desalinated water supply:

- Review of materials (pipes, appurtenances, household plumbing) to identify metals at risk of corrosion impacts from a new supply
- Post-treatment stabilization of water and/or blending to achieve a water quality that is non-corrosive toward existing pipe materials and scale/tuberculation;
- Consistency and gradual change in key water quality parameters (pH, chloride, sulfate, alkalinity);
- Bench and pilot testing to support to design decisions (e.g., confirmation of water quality targets for materials in the distribution system not thoroughly tested in past work and clearwell sizing for disinfectant stability).

5. Summary of Water Supply Integration Issues

The following table 5-1 provides an overall summary of the key issues identified for the integration of desalinated water from Doheny with existing imported and local groundwater supplies in the south orange county region and the recommended studies to support further project development.

Table 5-1: Summary of Integration Issues and Recommended Areas of Study

Issue	Recommended Study	Outcomes
Demand reduction at Diemer	Asset stranding optimization study	Recommended operating strategies at Diemer to minimize impacts to existing facilities. Consideration of implementation of both Huntington Beach and Doheny should be evaluated.
Overall Operational Strategy	Cost/benefit analysis (Diemer production versus Desal water)	Develop strategy to balance production from Doheny and imported water. Strategies should consider implementation of both Huntington Beach and Doheny. Identify facility requirements.
Low Demand Periods	Economic/Operational Analysis	Evaluate preferred method of operating the Doheny and Huntington Beach plants during low demand periods (cycling trains, idling trains, idling entire plant in favor of imported water).
Long Residence Times/Water Age	Hydraulic modeling	Identify potential stagnant areas and nitrification potential. Develop operational strategy to minimize water age.
System Operation Pumping/Storage Requirements	Hydraulic Model (in cooperation with MET's model)	Develop system operational strategy. Identify system HGLs and required system modifications.
Control of hydraulic transients	System Surge Analysis	Identify mitigation measures to protect system
Pipeline condition / pressure class incompatibility Impacts to existing facilities / local turnouts	Distribution System(s) Audit Pipeline Condition Assessment	Develop repair/ replacement program for pipelines and facilities identified as potentially impacted by hydraulic model.
DDW Requirements	Influence Model	Model anticipated system performance, water age and quality to satisfy DDW requirements
Water Quality Targets	Identification of Materials in Distribution Systems and Households Receiving Desalinated Water (Pipes, Appurtenances, Household Plumbing)	Pipe inventory and harvesting of representative pipes to assess interior condition.
Corrosion Control Testing	Bench and Pilot Testing of materials not thoroughly tested, e.g., galvanized pipe and pipe tuberculation	Identification of conditions to minimize corrosion outcomes.
Corrosion Potential	Pipe Material Survey; Identification of Materials in Distribution Systems and Households Receiving Desalinated Water (Pipes, Appurtenances, Household Plumbing)	Desktop study prediction of locations where new water supplies will interact with pipe materials of concern; identification of pilot testing if needed
Disinfectant Stability	Bench Testing of Chloramine Stability and DBP Formation	Clearwell sizing; determination of DBP formation if pre-membrane chlorination is planned; evaluate impact of brominated THM formation in blends of desal and Diemer water

Appendix A - References

Alsaqqar, A., Khudair, B.H., Ali, S. K., 2014. Evaluating Water Stability Indices from Water Treatment Plants in Baghdad City. Journal of Water Resource and Protection, 6:1344-1351.

Arnold, R.B., Edwards, M., 2012. Potential reversal and the effects of flow pattern on galvanic corrosion of lead. Environmental Science & Technology, 46:10941.

Arnold, R.B., Raetz, M., Edwards, M., 2011. Effects of Alkalinity, NOM, and Orthophosphate on Galvanic Corrosion. AWWA Annual Conference and Exposition, Washington, DC.

Arnold, R.B., Griffin, A., Edwards, M., 2012. Controlling copper corrosion in new construction by organic matter removal. Journal of the American Water Works Association, E310-317.

AWWA, 2005. Managing Change and Unintended Consequences: Lead and Copper Rule Corrosion Control Treatment. AWWA. Denver, CO. AwwaRF. 1990. Lead Control Strategies. AwwaRF Report #90559. Project #406. AWWA Research Foundation, Denver, CO.

AWWA, 2007. Reverse Osmosis and Nanofiltration. Manual M46, 2nd Ed.

AWWA, 2013. Nitrification Prevention and Control in Drinking Water. Manual M56, 2nd Ed.

AWWA and EES, Inc. 2002. Permeation and leaching. Available on-line at https://www.epa.gov/sites/production/files/2015-09/documents/permeationandleaching.pdf

AwwaRF, 1990. Lead Control Strategies. AwwaRF Report #90559. Project #406. AWWA Research Foundation and AWWA, Denver, CO.

AwwaRF and DVGW-Technologiezentrum Wasser, 1996. Internal Corrosion of Water Distribution Systems. 2nd edition. AwwaRF 90508, Project #725. AWWA Research Foundation, Denver, CO.

Benjamin, M.M., Sontheimer, H., and Leroy, P. 1996. "Chapter 2: Corrosion of Iron and Steel." Internal Corrosion of Water Distribution Systems. 2nd ed. American Water Works Association Research Foundation, DVGW-Technologiezentrum Wasser.

Berend, K. and Trouwborst, T. 1999. "Cement‐mortar pipes as a source of aluminum." Journal of the American Water Works Association 91(7), 91-100.

Blute, N.K., McGuire, M.J., West, N., Voutchkov, N., Maclaggan, P. and Reich, K., 2008. "Integration of Desalinated Seawater into a Distribution System". Journal of the American Water Works Association, 100(9), 117.

Bradley, T., 2018. Evaluation of Zinc Orthophosphtae to Control Lead Solder Corrosion in Waters with High Chloride to Sulfate Mass Ratio. Master's Thesis, Virginia Polytechnic Institute and State University.

Brown, R., McTigue, N., Cornwell, D., 2013. Strategies for assessing optimized corrosion control treatment of lead and copper. Journal AWWA, 105:62-75.

Cantor, A.F., Denig-Chakroff, D., Vela, R.R., Oleinik, M.G., and Lynch, D.L. 2000. "Use of Polyphosphate in Corrosion Control." American Water Works Association 21st Century Treatment and Distribution 92(2), 95-102.

City of San Clemente, 2016. 2015 Urban Water Management Plan. Arcadis.

City of San Juan Capistrano, 2011. 2010 Urban Water Management Plan. Malcolm Pirnie, Arcadis.

Crittenden, J.C., Trussell, R.R., Hand, D.W., Howe, K.J., Tchobanoglous, G., 2012. Water Treatment: Principles and Design. John Wiley & Sons, Hoboken, NJ.

Cavano, R.R., 2007. Saturation, Stability, and Scaling Indices. http://scrantonassociates.com/sssi.pdf. Visited September 14, 2017.

Der Merwe, V., 1988. "SW The Effect of Water Quality Variables on the Corrosive Behaviour of Water Coagulated with a Cationic Polyelectrolyte and with Lime/Activated Silica." Water Supply 6(4), 2.

Dewis, K., Boyd, G, Friedman, M., 2010. Blending Evaluation as a Tool for Managing Distribution System Water Quality. WIOA NSW Water Industry Engineers and Operators Conference.

Douglas, B.D., Merrill, D.T., and Catlin, J.O., 1996. "Water quality deterioration from corrosion of cement–mortar linings." Journal of the American Water Works Association 88(7), 99-107.

Duranceau, S.J.; Pfeiffer-Wilder, R.J.; Douglas, S.A.; Pena-Holt, N.; & Watson, I.C., 2011. Post-Treatment Stabilization of Desalinated Water. Water Research Foundation, Denver.

Edwards, M., Dudi, A., 2004. Role of chlorine and chloramine in corrosion of lead-bearing plumbing materials. Journal AWWA, 96(10): 69-81.

Edwards, M., Schock, M., Meyer, T.E., 1996. Alkalinity, pH, and copper corrosion by-product release. Journal AWWA, 88: 81-94.

Edwards, M. Sprague, N., 2001. Organic matter and copper corrosion by-product release: A mechanistic study. Corrosion Science, V. 43, No. 1, 1-18.

Edwards, M., and Triantafyllidou, S., 2007. “Chloride to sulfate mass ratio and lead leaching to water.” Journal of the American Water Works Association, 99:3.

Erdal, U.G., Suydam, T., and Lozier, J., 2013. “A comprehensive bench scale study to evaluate chloramine stability and DBP formation in distribution system carrying blended stream of desalinated and treated surface waters.”

Ferguson, J.F., von Franque, O., and Schock, M.R. 1996. “Chapter 5: Corrosion of Copper in Potable Water Systems.” Internal Corrosion of Water Distribution Systems. 2nd ed. American Water Works Association Research Foundation, DVGW-Technologiezentrum Wasser.

Frenkel, A.I., Korshin, G.V., 1999. EXAFS studies of the chemical state of lead and copper in corrosion products formed on the brass surface in potable water. Journal of Synchrotron Radiation, 6: 653-655.

Gebbie, P., 2000. Water Stability: What Does It Mean and How Do You Measure It? Water Industry Operators Association of Australia Conference Paper.

Imran, S.A., Dietz, J.D., Mutoti, G., Taylor, J.S., Randall, A.A., and Cooper, C.D., 2005. “Red Water Release in Drinking Water Distribution Systems.” Journal of the American Water Works Association 97(9), 93-100.

Kabay, N., Güler, E., and Bryjak, M. 2010. "Boron in seawater and methods for its separation—a review." Desalination 261(3), 212-217.

Kashinkunti, R. D., et al. "How to reduce lead corrosion without increasing iron release in the distribution system." Proc. 1999 AWWA WQTC, Tampa, Fla. 1999.

Kim, E.J., Herrera, J.E., 2010. Characteristics of lead corrosion scales formed during drinking water distri-bution and their potential influence on the release of lead and other contaminants. Environmental Science & Technology, 44(16): 6054-6061.

Kirmeyer, G.J., Murphy, B., Sandvig, A., Korshin, G., Shaha, B., Fabricino, M., and Burlingame, G., 2004. Post-Optimization Lead and Copper Control Monitoring Strategies. AWWARF 90996F, Project #2679. AWWA Research Foundation, Denver, CO.

Laguna Beach County Water District (LBCWD), 2016. 2015 Urban Water Management Plan. Karen E. Johnson, Water Resources Planning.

Lee, R.G., Becker, W.C., and Collins, D.W., 1989. “Lead at the Tap: Sources and Control.” Journal of the American Water Works Association 81(7), 52-62.

Li, S., Ni, L., Sun, C., and Wang, L., 2004. Influence of organic matter on orthophosphate corrosion inhibition for copper pipe in soft water. Corrosion Science, 46, 137-145.

Little, B.J., and Lee, J.S., 2014. “Microbiogically influenced corrosion: an update.” International Materials Reviews 59(7), 384-393.

Lytle, D.A., 2019. Personal communications.

Lytle, D.A., and Schock, M.R., 2008. “Pitting corrosion of copper in waters with high pH and low alkalinity.” Journal of the American Water Works Association 100(3), 115-129.

Lytle, 2017. “Corrosion of Distribution System Materials in Low Dissolved Inorganic Carbon (Alkalinity) Waters.” Metropolitan Water District of Southern California Expert Workshop, October 25, 2017.

Lytle, D., Sarin, P., and Snoeyink, V.L, 2005. The effect of chloride and orthophosphate on the release of iron from a cast iron pipe section. Journal of Water Supply: Research and Technology – AQUA, 54:5.

Lytle, D.A., and Schock, M.R., 2005. Formation of Pb(IV) oxides in chlorinated water. Journal of the American Water Works Association, 97(11): 102-114.

McNeill, L.S. and Edwards, M., 2001. “Iron pipe corrosion in distribution systems.” Journal of the American Water Works Association 93(7), 88-100.

Medlar, S. J.; Chalmers, R. B., 1994. Bench Scale Immersion Tests for Evaluating Lead and Copper Corrosion. AWWA Annual Conference and Exposition.

Moulton Niguel Water District (MNWD), 2016. 2015 Urban Water Management Plan.

Municipal Water District of Orange County (MWDOC), 2019. 2018 Orange County Water Reliability Study. CDM Smith, Inc.

Ng, D.Q., Strathmann, T.J., Lin, Y.P., 2012. Role of orthophosphate as a corrosion inhibitor in chloraminated solutions containing tetravalent lead corrosion product PbO2. Environmental Science & Technology, 46(20): 11062-9.

Nguyen, C., Stone, K., and Edwards, M., 2011. "Chloride-to-sulfate mass ratio: Practical studies in galvanic corrosion of leaded solder." Journal of the American Water Works Association 103(1), 81-92.

Nguyen, C., Stone, K., Clark, B. and Edwards, M., 2010. Impact of Chloride: Sulfate Mass Ratio (CSMR) Changes on Lead Leaching in Potable Water. Water Research Foundation and United States Environmental Protection Agency.

Nitrification Prevention and Control in Drinking Water. AWWA Manual M56, American Water Works Association, 2013 (AWWA, M56).

Ontario Ministry of Environment (OMOE), 2009. Guidance Document for Preparing Corrosion Control Plans for Drinking Water Systems.

Owen, C. 2019. Personal communications.

Parks, J., Edwards., M., Atassi, A., 2014. Non-Intrusive Methodology for Assessing Lead and Copper Corrosion. Water Research Foundation.

Pisigan Jr, R.A., and Singley, J.E., 1987. "Influence of Buffer Capacity, Chlorine Residual, and Flow Rate on Corrosion of Mild Steel and Copper." Journal of the American Water Works Association, 79(2), 62-70.

Pope, G., and Musullam, H., 2013. "Impacts of chloramine formation conditions on DBP formation and chloramine stability in a high-bromide source water." Presented at 2013 AWWA Annual Conference and Exhibition. Denver, Colorado.

Pope, P.G., Speitel Jr., G.E., and Collins, M.R. 2006. "Kinetics of Dihaloacetic Acid Formation during Chloramination." Journal of the American Water Works Association, 98(11), 107-120.

Raad, R., et al. "Selecting the Best Corrosion Control Strategy Using a New Rapid Corrosion Monitoring Tool." Proc. AWWA Water Quality Technology Conference, Paper 5C-1. San Diego, CA. 1998.

Rossum, J.R. and Merrill, D.T., 1983. An Evaluation of the Calcium Carbonate Saturation Indexes. Journal of the American Water Works Association, 75(2), 95-100.

Roth, D., Cornwell, D., Wagner, J., 2017. Bench-Testing of CCT for Surface Water/Groundwater Blends. AWWA Water Quality Technology Conference.

Santa Margarita Water District (SMWD), 2016. 2015 Urban Water Management Plan. Arcadis.

Sarin, P., Snoeyink, V.L., Lytle, D.A., Kriven, W.M., 2004. Iron corrosion scales: Model for scale growth, iron release and colored water formation. Journal Environmental Engineering, 130, 364-373.

Sarin, P., Snoeyink, V.L., Bebee, J., Jim, K.K., Beckett, M.A., Kriven, W.M., Clement, J.A., 2004. Iron release from corroded iron pipes in drinking water distribution systems: effect of dissolved oxygen. Water Research, 38(5): 1249-1269.

Sarin, P., Clement, J.A., Snoeyink, V.L., Kriven, W.M., 2003. "Iron Release from corroded, unlined cast‐iron pipe." Journal of the American Water Works Association 95(11), 85-96.

Schock, M.R., 1999. Internal corrosion and deposition control. In: Letterman, R.D. (Ed.), Water Quality and Treatment. McGraw-Hill, Inc., New York, New York.

Schock, M.R., Scheckel, K., DeSantis, M., Gerke, T., 2005. Mode of occurrence, treatment, and monitoring significance of tetravalent lead, AWWA WQTC, Quebec City.

Schock, M.R., Lytle, D.A., 2011. Chapter 20. Internal corrosion and deposition control. In: Edzwald, J.K. (Ed.), Water quality and treatment: A handbook of drinking water. McGraw-Hill, Inc., New York, New York.

Schock, M., 1989. Understanding corrosion control strategies for lead. Journal of the American Water Works Association 81(7), 88-100.

Schock, M.R., and Clement, J.A. 1998. "Lead and copper control with non-zinc orthophosphate." Journal of the New England Water Works Association, 112, 20-20.

Scott, K., and Tirtadidjaja, M., 2014. "Ocean Water Desalination Water Quality Integration Bench-Scale Study." Appendix B to the West Basin Municipal Water District, 2014. "Ocean Water Desalination Water Quality Integration Study." Final report, prepared by Hazen and Sawyer. http://www.westbasin.org/sites/default/files/desal-demo/wqis-project-final-report-063014.pdf

Shih, W.Y., Sutherland, J., Sessions, B., Mackey, E. and Walker, W.S., 2012. Upflow Calcite Contactor Study. Prepared for Texas Water Development Board.

South Coast Water District (SCWD), 2018. Draft Environmental Impact Report – Doheny Desalination Project. Kimley Horn.

South Coast Water District (SCWD), 2017. Infrastructure Master Plan. AECOM.

South Coast Water District (SCWD), 2016. 2015 Urban Water Management Plan. Arcadis.

Stanford, B.D., Becker, W., Debroux, J., Ishii, S., Khan, S., Khunjar, W., 2016. Planning for direct potable reuse: Operational aspects of an integrated drinking water system. Journal of the American Water Works Association, 108:4.

Stumm, W., 1960. "Investigation of the corrosive behavior of waters." Journal of the Sanitary Engineering Division 86(6), 27-46.

Tang, M., Nystrom, V., Pieper, K., Parks, J., Little, B., Guilliams, R., Esqueda, T., and Edwards, M., 2018. The Relationship between discolored water from corrosion of old iron pipe and source water conditions." Environmental Engineering Science 35(9).

Taylor, J., Dietz, J., Randall, A., and Hong, S., 2005. "Impact of RO-desalted water on distribution Water qualities." Water Science and Technology 51(6-7), 285-291.

Thompson K., Christofferson, W., Robinette, D., Curl, J., Baker, L., Brereton, J., Reich, K., 2006. Characterizing and Managing Salinity Loadings in Reclaimed Water Systems. AWWA Research Foundation, Denver, CO.

Triantafyllidou, S., Lytle, D., Rodgers, M., Muhlen, C., Elk, M., Boczek, L, Pfaller, S., Hoelle, J., Domingo, J.S., 2014. Challenges in Maintaing in Drinking Water Quality at Hospitals and Other Large Buildings. Ohio WEA-AWWA 2014 Technical Conference and Exposition.

Tri-Cities Municipal Water District, date unknown. Water Supply System Operations Description.

USEPA, 2016. Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems.

USEPA, 1993. Control of Lead and Copper in Drinking Water. Seminar Publication, EPA/625/R-93/001.

USEPA, 1992. Lead and Copper Guidance Manual. EPA 811-B-92-002.

Valentine, RL and Selleck KE. 1982. "Effect of Bromide and Nitrite on the Degradation of Monochloramine," Water Chlorination: Environmental Impact and Health Effects, Vol 4, Book 1, RL Jollet et al eds, Ann Arbor Science, pp 125-137.

Valentine, RL. 1998 "Chloramine Decomposition in Distribution Systems and Model Waters", AWWARF #937.

Videla, H.A., and Herrera, L.K., 2005. "Microbiologically influenced corrosion: looking to the future." International Microbiology 8(3), 169-180.

Vikesland, P.J., Ozekin, K., and R.L. Valentine. 2001. "Monochloramine Decay in Model and Distribution System Waters." Water Research, 35(7), 1766.

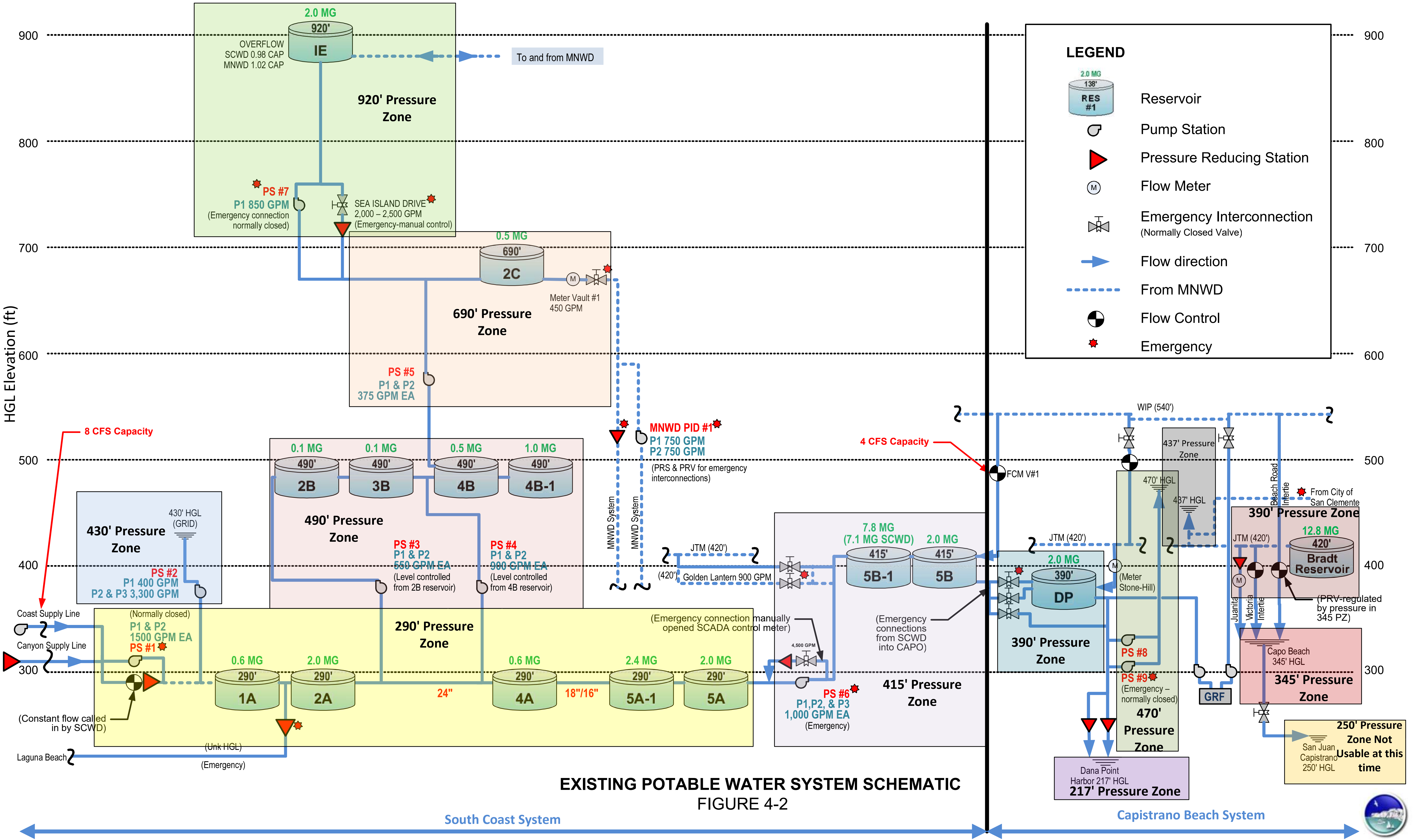
Wang, H., Pryor, M.A., Edwards, M., Falkinham III, J.O., Pruden A., 2013. Effect of GAC pre-treatment and disinfectant on microbial community structure and opportunistic pathogen occurrence. Water Research, 47 (15), 2013, 5760-5772.

World Health Organization. Safe drinking-water from desalination. No. WHO/HSE/WSH/11.03. Geneva: World Health Organization, 2011.

West Basin Municipal Water District, 2014. "Ocean Water Desalination Water Quality Integration Study." Final report, prepared by Hazen and Sawyer. http://www.westbasin.org/sites/default/files/desal-demo/wqis-project-final-report-063014.pdf

Zhang, Y., Tseng, T.J., Andrews-Tate, C., Cheng, R.C., and Wattier, K., 2012. "Pilot-Scale Evaluation of Blending Desalinated Seawater into a Distribution System", Journal of the American Water Works Association 104(7), 43.

Appendix B – SCWD Infrastructure Master Plan Figure 4-2



EXISTING POTABLE WATER SYSTEM SCHEMATIC

FIGURE 4-2

Appendix C – JTM and SCP/WIP HGL Profiles

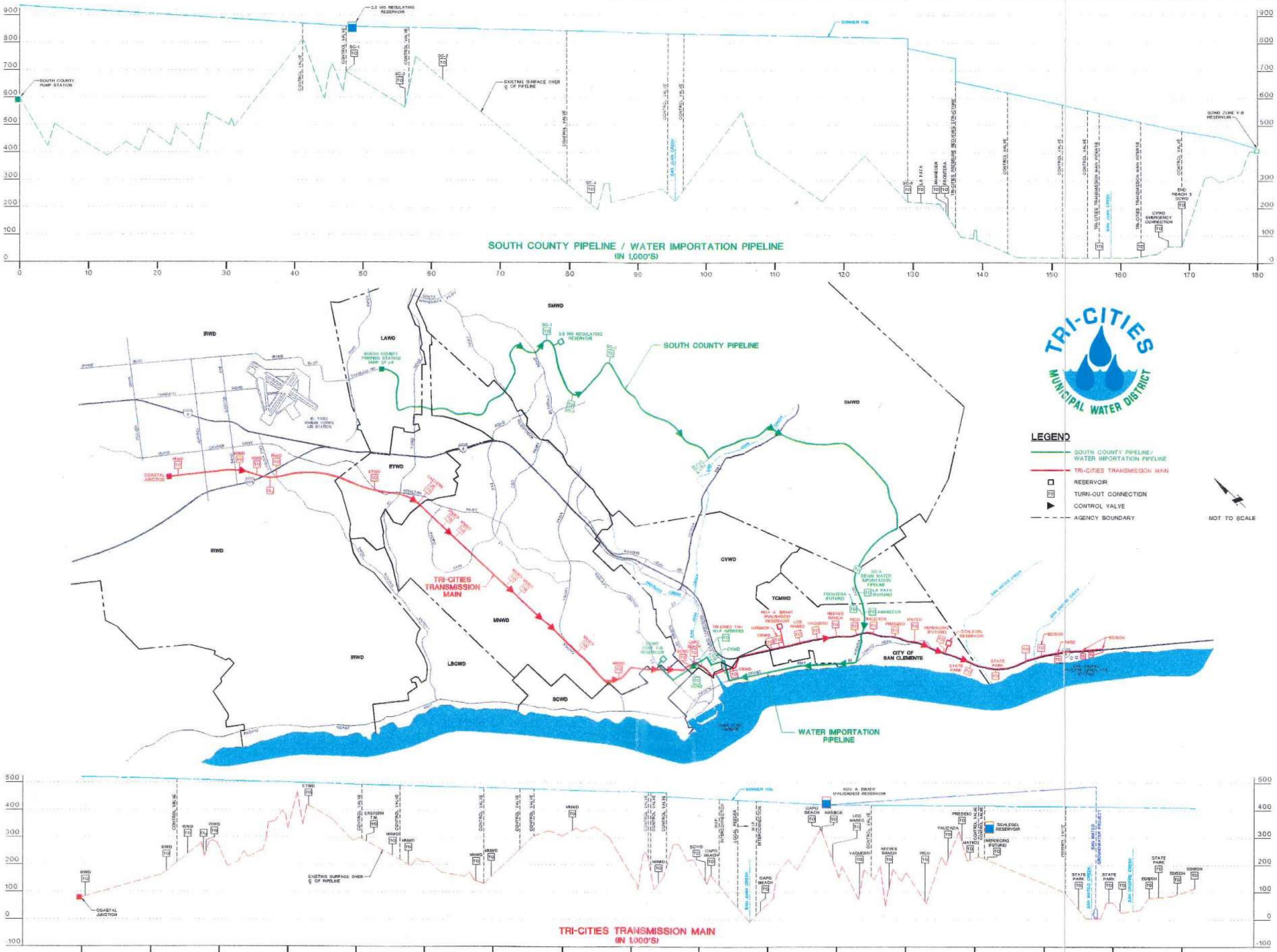

SOUTH COUNTY PIPELINE / WATER IMPORTATION PIPELINE
(IN 1,000'S)
SOUTH COUNTY PUMP STATION
3.0 MG REGULATING RESERVOIR
EXISTING SURFACE OVER ℄ OF PIPELINE
SCWD ZONE V-B RESERVOIR
SOUTH COUNTY PIPELINE
WATER IMPORTATION PIPELINE
TRI-CITIES TRANSMISSION MAIN
COASTAL JUNCTION
CITY OF SAN CLEMENTE
IRWD
LAWD
SMWD
ETWD
MNWD
LBCWD
SCWD
CVWD
TCMWD
TRI-CITIES MUNICIPAL WATER DISTRICT
LEGEND
SOUTH COUNTY PIPELINE/ WATER IMPORTATION PIPELINE
TRI-CITIES TRANSMISSION MAIN
☐ RESERVOIR
TO TURN-OUT CONNECTION
▶ CONTROL VALVE
AGENCY BOUNDARY
NOT TO SCALE
TRI-CITIES TRANSMISSION MAIN
(IN 1,000'S)
ROY A. BRADT (PALISADES) RESERVOIR
SCHLEGEL RESERVOIR

FIGURE 5

7.2 APPENDIX 2: MWDOC DATA REVIEW TECHNICAL MEMORANDUM 2019

BLACK & VEATCH

DATA REVIEW FOR THE HYDRAULIC MODEL DEVELOPMENT

Technical Memorandum

FINAL

B&V PROJECT NO. 402183

PREPARED FOR

MWDOC

Municipal Water District of Orange County

19 SEPTEMBER 2019

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1. Project Background and Introduction

The Municipal Water District of Orange County (MWDOC) previously retained the services of Black & Veatch, Hazen & Sawyer, and Means Consulting to work with MWDOC, Metropolitan Water District of Southern California (Metropolitan) and the OC retailers to more closely examine future operating scenarios for the Regional Orange County water system and introduction of new supplies. The need for this work arose based on several observations or studies:

- A January 2017 operating condition (a very wet month) that resulted in extremely low demands on Metropolitan's Diemer Filtration Plant in Yorba Linda (Diemer) with flows in the OC Regional Water Distribution system as low as 5 cfs in 78-inch and larger diameter pipelines; leading to extremely long residence times.
- MWDOC's completion of several studies and various scenario evaluations of options to ensure a sustainable and reliable water supply for its member agencies. The Orange County (OC) Water Reliability Study (Reliability Study), which was completed in 2016 and updated in 2018, captures these efforts and its results. The updated Reliability Study identified four regional supply projects that could be implemented in OC to provide supply locally to enhance system reliability. These include two proposed desalination plants: the proposed Huntington Beach Desalination Plant (HBDP) being privately developed by Poseidon Water, and the proposed South Coast Water District Doheny Desalination Plant (DDP). The other two possible regional supply projects involve increased use of Orange County Water District (OCWD) groundwater. In addition, other local supplies may be integrated into the OC Regional Water distribution system, such as the San Juan Watershed Project.
- The Reliability Study also concluded that implementation of base-loaded projects in South Orange County (SOC) above approximately 10 mgd may have problems operating during low demand months; and base-loaded projects greater than 20 mgd may have problems operating in the other remaining portions of the year for South Orange County over the long term.
- Planning considerations for integration of the 50 mgd Poseidon Ocean Desalination Project indicate that imported treated demands from Diemer from within the OCWD portion of Orange County may be as low as about 5 mgd if the full capacity of the Poseidon Project is integrated just for the OCWD groundwater basin area. Metropolitan has indicated that they have problems when operating the Diemer Plant at or below 70 mgd (Diemer provides flows to OC and to portions of LA County, so 70 mgd of demands for imported water must come from the combined service areas). To operate consistently at levels below 70 mgd Metropolitan would have to complete substantial (and costly) retrofits to the plant's chemical feed and control systems.
- The observation that potentially low levels of imported water deliveries in certain pipelines at certain times of the year can lead to low chloramine residuals and water quality deterioration (e.g. nitrification).
- Planning considerations for pumping emergency groundwater into the EOCF#2 to be conveyed to SOC during emergency outage events.
- Planning considerations for many potential extended shutdowns of the AMP needed to reline approximately 9 miles of Prestressed Concrete Cylinder Pipe (PCCP).
- Planning in OC to deal with the issue of PFAS impacting wells and the operations of the retail agencies

- Planning considerations for integration/mixing of desalinated seawater with other sources of water of varying quality including:
    - Poseidon Water from Huntington Beach
    - Doheny Water from Dana Point
    - Chloramine loss due to reaction with low levels of bromide in seawater permeate
    - The pH, alkalinity, TOC, bromide, chloramine residual, and other water quality characteristics; which may vary among these water sources, Metropolitan water and groundwater quality on daily, monthly and seasonal bases. Planning needs to account for the water quality and operational considerations or risk of unintended consequences. Our goal is to understand the issues **prior** to any of these projects going on-line.
- Understanding and developing approaches for dealing with water quality consequences to home plumbing systems
- Potential impacts on the Diemer Plant operations or stranding of assets, especially under conditions of unexpected outages of local supply systems
- Working out an acceptable resolution with Metropolitan for integrating local supplies of varying water quality into the EOCF#2
- Control of hydraulic transients during loss of power

Black & Veatch and Hazen & Sawyer were asked to review the above issues and identify and prioritize how best to address these issues over time. Each consultant prepared a white paper covering certain locations or types of supply projects and to consider what information exists related to issues of integrating the new supplies or changed operations into effect. The issues from the white papers can be grouped into the following categories:

1. Operational Scenarios - Development of operational scenarios to outline the potential water quality or operational situations that may arise in the future.
    a. Examine how these scenarios change between low demand and high demand periods and how far water from the various sources may travel in the system.
    b. Examine the issues associated with starting or stopping any supply source or areas where flows may reverse or stagnate.
    c. Impacts with underutilized or stranded portions of the import system should be identified. Metropolitan's Diemer Plant supplies should be reviewed to ensure at least 70 mgd of demands remain on the plant, the lowest operational output (13%) of the 520 mgd plant without resulting in operational difficulties and additional costs for Metropolitan (which would then be passed on in higher water rates).
    d. A review of the operations of the Baker Treatment Plant should be made to ensure it continues with a base-loaded operation of about 43.5 cfs (28 mgd).
    e. New projects for SOC need to be reviewed to determine if they can be integrated on a base-load operation or if production may have to be trimmed back in low demand months, possibly increasing the costs from the project.
2. Potential Impacts to Water Quality and Piping Materials – The white papers provided by the two consultants outlined potential impacts from blending water of various sources. Potential impacts to regional or home piping include:

   a. Iron leaching in the presence of chloride or sulfate ions until equilibrium is reached; changing water quality can upset the equilibrium and restart the leaching process; higher alkalinity water helps reduce the impacts.
   b. Boron impacts to agriculture/horticulture.
   c. Bromide impacts to the chloramine residual.
   d. Water age impacts due to nitrification.

3. Development of a Hydraulic Model – Metropolitan has agreed to provide pipe and node information along with GIS information of their pipelines in Orange County which includes about eleven pipelines; there are about twelve pipelines downstream of the Metropolitan system to complete the remaining portion of the regional OC pipeline system serving water in Orange County to make up a simple system of about 23 pipelines for the backbone system. MWDOC anticipates that the backbone system will be constructed and organized in such a way that member agency demands can be assigned to various node points to allow the demands on various pipes to be developed from demand projections by the member agencies. The hydraulic model will provide an opportunity to examine:
   a. The range of flows in the system between high and low demand periods
   b. Emergency operations
   c. Shutdown Planning operations
   d. Water age and chloramine decay tracking
   e. Mixing of blends of water for system integration purposes
   f. Other kinetic changes to water quality from blending, e.g., bromide impacts on the chloramine residual.
4. Other Considerations Outlined in the white papers:
   a. Water Quality of New Sources – The pH, alkalinity, TOC, bromide, chloramine residual, and other water quality characteristics will differ by source. Need to understand the implications of mixing with Metropolitan and groundwater supplies. It is already understood that higher levels of bromide from ocean water can result in the decline of the chloramine residual. Jar testing can help understand the kinetics of this reaction in the presence of various other sources of water.
   b. Items to Include in Design Reports for New Sources of Supply
      i. Capital and O&M costs
      ii. Permitting of NEW Sources by DDW
      iii. Non-spec water response – potentially requires engineered buffer
      iv. Boron/Bromide targets for ocean water – consider bromide levels less than 0.3 mg/l to minimize disinfectant decay, potential NDMA formation and increases in brominated DBPs in Metropolitan water. Consider boron target less than 0.5 mg/l to protect plants.
      v. Red tide events for ocean water
      vi. Fluoride dosing of imported water
      vii. Need for Chloramine Booster Stations

viii. Regional Pipeline Materials
ix. Home Plumbing Pipe Materials
x. Virtual Service Connection with Metropolitan if OC wants to pump local water sources into a Metropolitan pipeline (a virtual service connection defines the delineation for responsibility for water quality with the Metropolitan responsibility upstream of a point of connection and OC responsible for downstream of where an alternate source is pumped in).

Any or all of the projects noted in the Reliability Study could be integrated into the existing OC Regional Water Distribution system. MWDOC is seeking to develop information and analytical tools to facilitate the study of the potential effects (hydraulic, water quality, operational, etc.) of the introduction of new supplies into the existing system. A primary analytical tool identified in the white papers was a hydraulic model of the OC Regional Water distribution system. A hydraulic model could be used to assess any or all of the operating issues noted above so that new infrastructure can be planned that provides benefits to OC member agencies and customers while mitigating or eliminating negative issues.

MWDOC awarded the Phase 1 of hydraulic model development to Black & Veatch. Phase 1 is comprised of an evaluation of the uses for a hydraulic model, based primarily on the needs of MWDOC's member agencies, and those of the owner and operator stakeholders of the OC distribution system. Said evaluations will be used to make decisions relative to moving forward with developing a hydraulic model, selecting the appropriate modeling software platform, and developing an Implementation Plan for the model, including potential phasing.

This technical memorandum summarizes the first task in Phase 1: the review of the data available from various sources that can be used to support model development, and identification of any gaps that might be present in the available data. This memorandum lists information available that will support building the hydraulic model and the quality and completeness of the data to meet MWDOC's project objectives. The availability and quality of data will inform the selection of the modeling software platform and assist in the development of the Implementation Plan. Where missing information or data gaps are identified, data collection programs and other assessments would be proposed.

2. Available Data and Evaluation

Black & Veatch developed a System Information Database to summarize the available data and information (Appendix 1). The database organizes the data into different categories and documents its source, format, and date when the data was received. The requested data were broadly classified into the below categories. Each category had multiple data elements.

- Demand and Supply Data
- Water Quality Data
- Hydraulic Model Data
- GIS Data
- Operational Data

- Miscellaneous Data

Most of the requested data was available in one form or another. Some of it was provided to Black & Veatch for Phase 1. If not provided, the details on the availability of the rest of the data were provided. Based on this, each data item was reviewed and was categorized based on its completeness and relevance to the hydraulic model build (Table 1).

2.1 DEMAND AND SUPPLY DATA

2.1.1 Historical Supply Data (A1, A2, and A3)

MWDOC and its agencies receive imported water supply from Metropolitan and groundwater supply from Orange County Water District (OCWD). The historical data from these supplies are essential to building the hydraulic model since they will be used as inputs (source and demands) into the hydraulic model. Metropolitan has flow meters at all its turnouts and flow data in spreadsheet format was provided for a 5-year period (2014-2018) at 15-minute intervals. A brief review of the data did not reveal any anomalies in the data. Not all of this data is needed for the model build. The data from turnouts needed for the hydraulic model development should be reviewed and updated prior to the model build. Metropolitan's system service meters are calibrated twice per year and deemed to provide a level of accuracy sufficient for system hydraulic modeling and planning.

OCWD provided monthly groundwater delivery data to all the MWDOC member agencies also in spreadsheet format. The water delivery data was categorized as OCWD Basin Groundwater, Non-OCWD Groundwater, Recycled Water, Replenishment Recycled Water, and Surface Water (defined as imported water from Metropolitan). Average, Peak and Low demand period supply and demand information can be extracted from this data. More detailed flow information might be needed for some agencies to calculate diurnal variations for the flows although import water deliveries are typically fairly constant over a 24-hr period unless emergencies or other special operations or emergencies occur.

2.1.2 Future Supply Portfolio (A4, A5)

Information on OC's future supply portfolio is available in Chapter 5 of the Reliability Study. This report is available on MWDOC's website and outlines the future supply options for MWDOC customers. These future options include local desalination projects like the HBDP, DDP, and increased groundwater pumping from the OC basin into the East Orange County Feeder No. 2 (EOCF2) and West OC Water Board (WOCB) Feeders. The planned capacity of these projects was summarized in the 2018 Reliability Study, along with tentative locations. These capacities (or range of capacities) should be confirmed during the model development process so that appropriate scenarios can be created in the model. The exact locations of the future supplies could not be confirmed during this data review task but must be completed during the model development process.

Table 1. Summary of Data Requested, Reviewed, and Availability

#	Description	Importance for Hydraulic Model Development			Availability			
		Background	Potential Use	Essential	Requested - Not Provided Yet	Significant Gap	Partially Available	Completely Available
A. DEMAND AND SUPPLY DATA								
A1	Historical supply data from Metropolitan to MWDOC agencies for the past 5 years (including specific turnouts)			✘				✘
A2	Historical supply data from OCWD to MWDOC agencies for the past 5 years			✘				✘
A3	Historical other local supply data for the past 5 years			✘				✘
A4	Future supply portfolios (including the timing of any new supplies)			✘				✘
A5	Location of all existing and future water supplies		✘	✘	✘			
A6	Existing and future demands for MWDOC member agencies			✘				✘
B. WATER QUALITY DATA								
B1	Historical imported water quality data for source and supplied water (to member agencies) such as disinfection concentration (chlorine/chloramines)	✘			✘			
B2	Locations of water quality data collection or sampling points (TCR and other such locations)	✘			✘			
B3	Water quality reports/studies by member agencies	✘			✘			

C. HYDRAULIC MODEL DATA								
C1	List of agencies with hydraulic models, software used, and last calibration date	✘			✘			
C2	List of uses of the hydraulic model by agencies including water quality modeling and new source water integration analysis				✘			
C3	Metropolitan's MIKE Urban model			✘			✘	
D. GIS DATA								
D1	GIS database for all regional pipelines, distribution pipelines, reservoirs, pump stations, treatment plants, pressure control facilities, valve vaults, etc.	✘		✘			✘	
E. OPERATIONAL DATA								
E1	Reports and documents describing/outlining the operations of Metropolitan's/MWDOC regional system under different supply, demand, and seasonal variations	✘						✘
F. MISCELLANEOUS DATA								
F1	Previous reports/study on the hydraulics or modeling of MWDOC's system	✘						✘
F2	Previous reports/study on OC's Regional Water Distribution system	✘						✘

2.1.3 Existing and Future Demands (A6)

Along with the Reliability Study, the 2016 MWDOC Urban Water Management Plan (UWMP) was downloaded from MWDOC's website. The Reliability Study outlines the future supply needs for Orange County (Chapter 4) and the 2016 UWMP summarizes the MWDOC service area projected demands for 2020 to 2040 in 5-year intervals (Chapter 2). The demands used in both studies were developed in the middle of the 2012 to 2016 California drought and reflect an approximate 23% drop in demands and rebound following the drought. The out-year projections assume future developments are much more efficient from a water demand perspective and that continuing investments are made to reduce demands in older areas of the County. The drought rebound is 85% over 5 years and up to 90% over 10 years. These demands can be used to assign average, peak or low demands to the hydraulic model. Individual UWMP or Master Plans can be obtained from the member agencies to establish more granular demands data (existing and future) and to assign them spatially to the model. MWDOC is also expecting Metropolitan's 2020 IRP to include detailed analysis of demands and demand forecasts over time that might serve to inform the demand forecasts in OC.

2.2 WATER QUALITY DATA (B1, B2, AND B3)

The effect of potential regional supply projects on water quality is a key topic of interest to MWDOC and a primary reason for the hydraulic model development. Historical imported and local water quality data was requested from MWDOC and Metropolitan, along with the locations where this data was collected. At a meeting at Metropolitan in June 2019, MWDOC and Metropolitan confirmed that this data was available and will be provided when the model is built and ready for water quality calibration. During model development, Black & Veatch will work closely with MWDOC and Metropolitan to collect the detailed water quality data and confirm that there are enough data points across the system at sufficient time intervals to calibrate/validate a water quality model. If necessary, a water quality sampling plan should be developed to collect additional data.

2.3 HYDRAULIC MODEL DATA

2.3.1. Hydraulic Models from Member Agencies

Although not imperative to successful model development, it would nonetheless be desirable for MWDOC's future hydraulic model to be compatible with the hydraulic models of its member agencies. Compatibility does not necessarily mean the same software platform but compatible models will allow efficient transfer of data between different hydraulic models, to facilitate collaboration and coordination between MWDOC and its member agencies on matters related to water supply planning and system operation.

To help assess compatibility, Black & Veatch requested information on any hydraulic models that have already been developed by MWDOC's member agencies, including the software used and last calibration date. Information on specific uses of the hydraulic model by member agencies was also requested. To facilitate this, MWDOC with support from Black & Veatch created a short questionnaire (Appendix 2) that was distributed to the member agencies. Once completed and returned to MWDOC, the collected data will be analyzed by Black & Veatch as part of this project and will assist in the evaluation and selection of the most appropriate software platform for OC's hydraulic model.

2.3.2. Metropolitan's Hydraulic Model

Metropolitan maintains a hydraulic model in MIKE URBAN software for its pipelines and conveyance infrastructure. Metropolitan is one of MWDOC's OC distribution system owner and operator stakeholders. OC's hydraulic model will thus need to include some of Metropolitan's pipelines and conveyance infrastructure in OC. Model information on these pipelines and conveyance infrastructure can be easily be imported from Metropolitan's hydraulic model and utilized to build OC's hydraulic model. Black & Veatch requested a copy of Metropolitan's hydraulic model to assist with the model build and confirm its inputs. Metropolitan, in a meeting June 2019, agreed to share the Geographic Information System (GIS) files exported from the MIKE URBAN model which will help with the model build. The list and extent of this information are provided in Appendix 3. The model export will include information on links (pipelines), model nodes, valves, orifices, weirs, and pumps. This will be provided to MWDOC and Black & Veatch after the execution of a non-disclosure agreement.

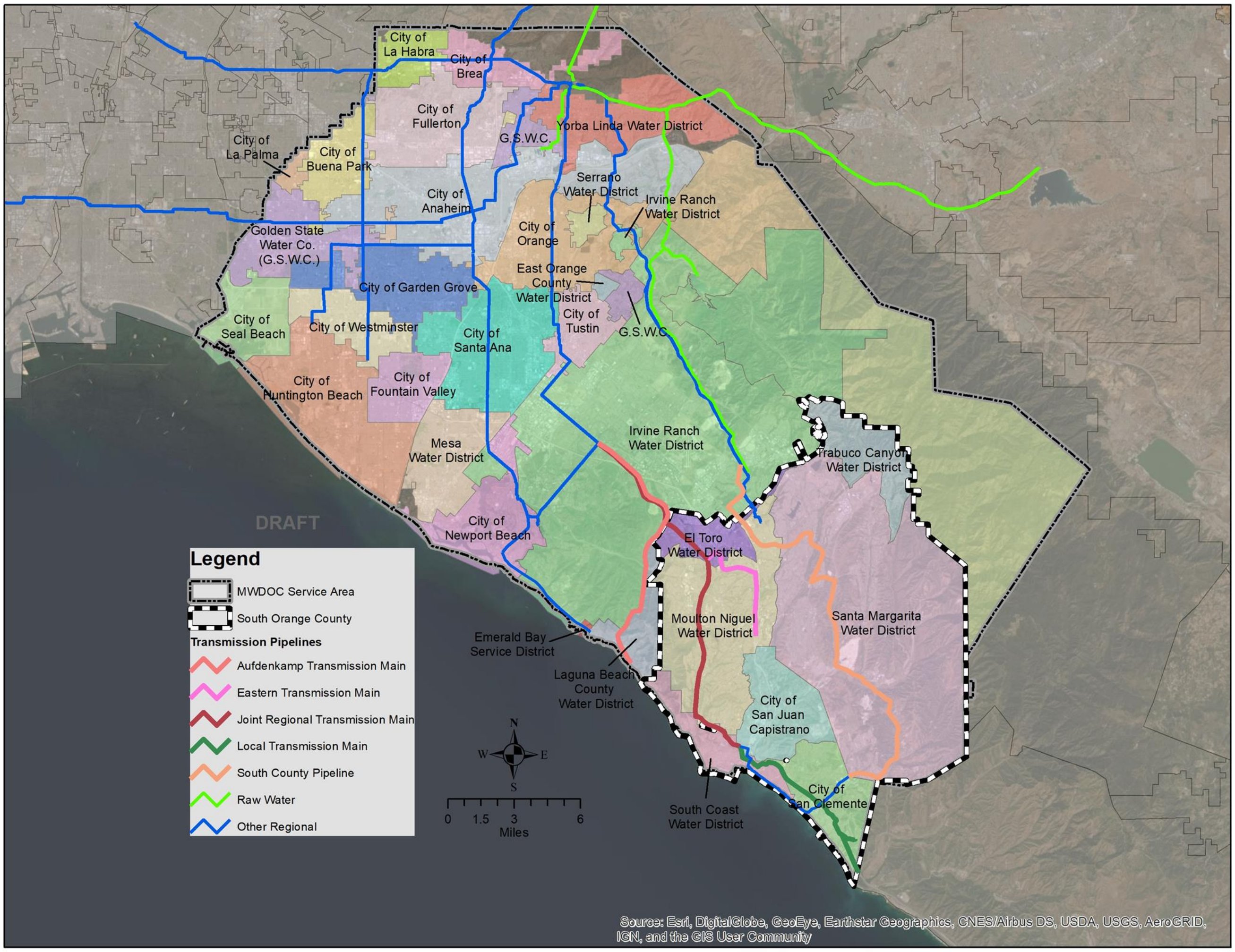
2.4 GIS DATA

GIS data is generally the main source of data for the hydraulic model. GIS data was requested for all the pipelines and conveyance infrastructure in the MWDOC service area, irrespective of the ownership of the infrastructure.

As noted in Section 2.3.2, Metropolitan will provide its hydraulic model data in GIS format for its infrastructure in the MWDOC service area. South Orange County (SOC) is not part of the Metropolitan owned system. MWDOC's member agencies in SOC (Figure 1) include El Toro Water District (ETWD), Moulton Niguel Water District (MNWD), South Coast Water District (SCWD), the City of San Juan Capistrano, the City of San Clemente, Santa Margarita Water District (SMWD), and Trabuco Canyon Water District (TCWD). These agencies are served by pipelines that are owned and operated by individual agencies in this group or various partnerships thereof. GIS data for the transmission pipelines serving these agencies were requested including data for:

- South County Pipeline
- Eastern Transmission Main (ETM)
- Joint Regional Transmission Main (JTM)
- Aufdenkamp Transmission Main (ATM)
- Local Transmission Main (LTM)

MNWD provided GIS data to Black & Veatch for most of these pipelines. The GIS attributes included its diameter and material, which are essential to the hydraulic model. This data should be suitable to build the SOC part of OC's hydraulic model. SMWD noted that it is currently developing its GIS database and will be completed in mid-2020. SMWD will have the data for the South County Pipeline.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1. South Orange County Agencies and Transmission Lines

Our review suggests that there is sufficient GIS data from Metropolitan and MWDOC's member agencies to build an OC hydraulic model. If GIS data is not available for some part of MWDOC conveyance system, that part of the model will need to be digitized manually using as-built or other available drawings for those transmission lines. For this data review, it was not verified if as-built drawings are available for all transmission lines with no GIS data.

2.5 OPERATIONAL AND MISCELLANEOUS DATA

Understanding the operations of the OC transmission system is critical in developing and calibrating the hydraulic model. The operations of the various pipelines, facilities, and turnouts have been documented by both Metropolitan and MWDOC. Black & Veatch was given access to hydraulic profiles for Metropolitan pipelines, which has hydraulic data for most pipes. MWDOC has prepared two white papers focused on the integration of new local water supplies like desalination and new groundwater. These documents summarize the description and operations of East Orange County Feeder No. 2 and other OC transmission lines. Physical and water quality issues with the integration of these new sources are also summarized in these white papers. Such information combined with interviews with the operational staff should provide sufficient information to build OC's hydraulic model.

3. Conclusion

GIS data along with supply-demand information is critical to building a hydraulic model. This data is readily available from MWDOC, Metropolitan, and MWDOC's member agencies. This will enable a good hydraulic model build for MWDOC. No significant data gaps are identified in developing the hydraulic model from this data review task. Developing a good and usable water quality model from this hydraulic model will depend on the availability of good water quality data at sufficient intervals. Such data is available and will be obtained prior to the model build.

APPENDIX 1: System Information Database

APPENDIX 2: Hydraulic Model Questionnaire

APPENDIX 3: List of GIS data extracted from MIKE URBAN model to be provided by Metropolitan

APPENDIX 1 - System Information Database

Municipal Water District of Orange County
OC Distribution System Water Supply Integration Hydraulic Model
Phase 1 - Model Investigation
System Information Database (Requested date: May 2, 2019)

Priority Legend: High | Medium | Low | Received

Last Update: 08/1/2019

#	Description	Format	Source	Responsible Person	Date Needed	Date Received	Notes
A. DEMAND AND SUPPLY DATA							
A1	Historical supply data from MET to MWDOC agencies for past 5 years (including specific turnouts)	Digital (GIS or Excel)	MET		5/20/2019	6/3/2019	Five year of MWD turnout data at 15 minute intervals (excel)
A2	Historical supply data from OCWD to MWDOC agencies for past 5 years	Digital (GIS or Excel)	MWDOC		5/20/2019	6/3/2019	Monthly consumption data (excel) by member agency for 5 years (2014 - 2018)
A3	Historical other local supply data for past 5 years	Digitial (GIS or Excel)	MWDOC / Agencies		5/20/2019		Monthly consumption data (excel) by member agency for 5 years (2014 - 2018)
A4	Future supply portfolios (including timing of any new supplies)	Any	MWDOC / Agencies		5/20/2019	5/9/2019	Dowloaded 2018 OC Reliability Study report from MWDOC website
A5	Location of all existing and future water supplies	GIS	MWDOC / Agencies		5/20/2019		To be provided by MWDOC
A6	Existing and future demands for MWDOC member agencies	Digitial (GIS or Excel)	MWDOC / Agencies		5/20/2019	5/9/2019	Dowloaded 2018 OC Reliability Study report
B. WATER QUALITY DATA							
B1	Historical imported water quality data for source and supplied water (to member agencies) such as disinfection concentration (chlorine/chloramines)	Any	MWDOC / MET		5/20/2019		MWDOC is gathering the information
B2	Locations of water quality data collection or sampling points (TCR and other such locations)	Any	MWDOC / MET		5/20/2019		MWDOC is gathering the information
B3	Water quality reports/studies by member agencies	Any	MWDOC / Agencies		5/20/2019		MWDOC is gathering the information
C. HYDRAULIC MODEL DATA							
C1	List of agencies with hydraulic models, software used, and last calibration date	Spreadsheet	MWDOC / Agencies		5/20/2019		Questionnaire developed and submitted to MWDOC
C2	List of uses of hydraulic model by agencies including water quality modeling and new source water integration analysis	Spreadsheet	MWDOC / Agencies		5/20/2019		Questionnaire developed and submitted to MWDOC
C3	MET's MIKE Urban model	MIKE Urban file	MET		5/10/2019		MWDOC to provide GIS files from their model for MWDOC service area
D. GIS DATA							
D1	GIS database for all regional pipelines, distribution pipelines, reservoirs, pump stations, treatment plants, pressure control facilities, valve vaults, etc	GIS geodatabase	MWDOC / MET		5/10/2019		See D1; Received data from Moulton Niguel
E. OPERATIONAL DATA							
E1	Reports and documents describing/outlining the operations of MWD's/MWDOC regional system under different supply, demand, and seasonal variations	Word / PDF	MWDOC		5/20/2019		
F. MISCELLANEOUS DATA							
F1	Any previous reports/study on the hydraulics or modeling of MWDOC's system	Word / PDF	MWDOC		5/10/2019	5/17/2019	Use developed White Papers
F2	Any previous reports/study on MWDOC's water conveyance system	Word / PDF	MWDOC		5/10/2019	5/17/2019	See above

OC Distribution System Water Supply Integration Hydraulic Model:
Phase 1 – Model Investigation

Distribution System Hydraulic Model Questionnaire

The Municipal Water District of Orange County (MWDOC) is considering developing a hydraulic model of the backbone water distribution system in Orange County. It is envisioned that this model will be used to evaluate the integration of new local water supplies into the existing system. Such evaluations could include determining the physical limitations of the existing system to convey new supplies, identifying impacts on existing facility operations, determining the extents and impacts of any changes in water quality parameters and regulatory compliance, and defining any facility improvement needs.

MWDOC foresees that development of an Orange County focused, regional system model, will be useful not just for regional water supply planning but may be of benefit to its Member Agencies on an individual basis. As part of Phase I of its hydraulic model evaluation, MWDOC is establishing the potential end uses for such a model, and selecting a modeling platform that is cost-effective and best addresses those needs. As part of this evaluation, MWDOC is interested in selecting a modeling platform that would be of most benefit to its Member Agencies.

To that end, MWDOC is seeking to gather information about to what extent each Member Agency has their own hydraulic models and geographic information system (GIS) data as it may be desirable for MWDOC to select a modeling platform that is most compatible with Member Agency uses. MWDOC is also interested in learning about potential end uses each Member Agency can foresee for an Orange County focused, regional system model so that the selected platform can fulfill those needs.

MWDOC appreciates your support of its evaluation by answering the following brief questionnaire:

1. Has your agency developed a distribution system hydraulic model for your system?

   ☐ Yes

   ☐ No

   If you answered Yes to the previous question, please continue to the next question below. Otherwise, please skip to Question 6.

2. What software is the model built-in?

   ☐ Bentley WaterCAD/GEMS
   ☐ Innovyze Infowater
   ☐ DHI MIKE Urban
   ☐ Innovyze Infoworks
   ☐ EPANET
   ☐ Others. Please Specify Software Name: ____________________________________

3. When was the model last calibrated? ____________________________________

4. For what type of analyses is/has the model be been used?

   ☐ Master Planning
   ☐ Hydraulic Analysis
   ☐ Fire Flow Analysis
   ☐ Water Quality Analysis
   ☐ Operational Efficiency Analysis
   ☐ Others. Please Specify:____

5. Please summarize your agencies future goals, needs, and aspirations related to the hydraulic modeling.

6. Does your agency utilize a geographic information system (GIS)?

   ☐ Yes
   ☐ No

7. If your agency does have a geographic information system (GIS), what software platform do you utilize?____

8. Please describe briefly for what purposes your agency utilizes GIS:

   ____

   ____

   ____

9. Provide a general indication of the current state of your agency's GIS:

   ☐ Robust and accurate data

   ☐ Some aspects are complete and accurate, others are still in development

   ☐ We are just getting started developing a GIS for our agency

10. Briefly explain your response to Question #9.

    ____

    ____

    ____

11. What are your near and longer term plans for your GIS?

    ____

    ____

    ____

MWDOC thanks you for your participation.

Name: ______________________________

Contact Number: ________________________

Email: ______________________________

APPENDIX 3

GIS extract from Metropolitan's hydraulic model

Link

- Link ID
- From Node
- To Node
- Upstream Invert Elevation
- Downstream Invert Elevation
- Length
- Diameter
- Material
- Manning's Roughness

Node

- Node ID
- Invert Elevation
- Minor Loss Coefficient
- Ground Elevation
- Manhole Type (Closed/Spilling/Fictive)

Valve

- Valve ID
- From Node
- To Node
- Invert Elevation
- Diameter
- Rating Curve (Provided separately in tabular format)

Orifice

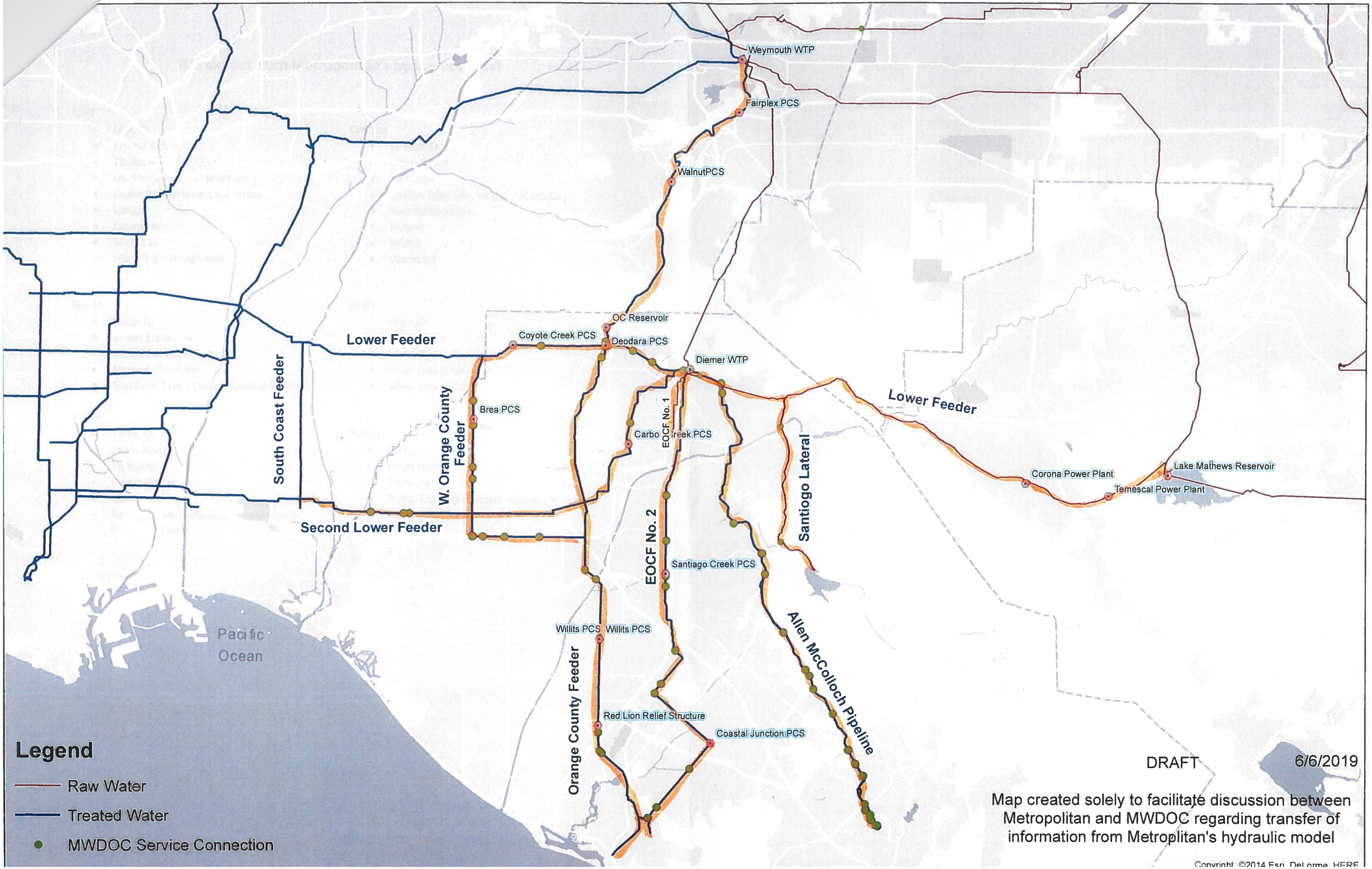
- Orifice ID
- From Node
- To Node
- Orifice Type (Rectangular/Circular)
- Invert Elevation
- Height
- Width
- Diameter

Weir

- Weir ID
- From Node
- To Node
- Weir Crest Elevation
- Weir Crest Width

Pump

- Pump ID
- From Node
- To Node
- Pump Curve (Provided separately in tabular format)



Legend

— Raw Water

— Treated Water

● MWDOC Service Connection

DRAFT

6/6/2019

Map created solely to facilitate discussion between Metropolitan and MWDOC regarding transfer of information from Metroplitan's hydraulic model

7.3 APPENDIX 3: MWDOC MODELING SOFTWARE DECISION MATRIX 2020

Software Market Survey Results and Selection Decision Support Tool

No.	***MWDOC Needs/Goals***	***Software Capability Criteria***	***InfoWater***			***MIKE Urban***			***WaterGEMS***		
			Functionality Description	***Score***	***Weighted Score***	***Functionality Description***	***Score***	***Weighted Score***	***Functionality Description***	***Score***	***Weighted Score***
1	Simulation of full-pipe pressurized flow conditions which normally exist in most areas of MWDOC's system, as well as, partially-full unpressurized flow conditions in some areas of the system (i.e. Santiago Lateral)	Ability to perform pressurized flow hydraulics?	Yes	2	6	Yes	2	6	Yes	2	6
		Ability to perform or represent open channel flow hydraulics?	No, not intended to model open channels	0	0	Yes, MIKE Urban can model distribution, collection, and drainage	2	2	No, not intended to model open channels	0	0
2	Simulation of steady-state, time-varying (dynamic or extended period simulation (EPS)), and transient (surge) hydraulic conditions	Ability to perform steady-state hydraulics?	Yes	2	6	Yes	2	6	Yes	2	6
		Ability to perform time-varying hydraulics?	Yes	2	6	Yes	2	6	Yes	2	6
		Ability to perform transient hydraulics?	No, but compatible software InfoSurge can also be used as add on module	1	2	No; expected to be added in a future release	0	0	No, but compatible software Bentley Hammer can be used as compatible software	1	2
3	Hydraulic simulation of treatment plant supplies, pumping stations, storage facilities, pressure/flow regulating stations, and demand/flow transfer points	Ability to simulate same?	Yes	2	6	Yes	2	6	Yes	2	6
4	Compatibility with MET's Mike Urban model and/or ability to import model data to support model build	Ability to import Mike Urban models and/or GIS data exported from Mike Urban?	Yes; able to import GIS shapefiles exported from a Mike Urban model	2	2	Yes; directly capable of exporting other MikeUrban model	3	3	Yes; able to import GIS shapefiles exported from a Mike Urban model	2	2
		Ability to import EPANet models exported from Mike Urban?	Yes; able to import .inp (EPANet) files	2	2	Yes; able to import .inp (EPANet) files	2	2	Yes; able to import .inp (EPANet) files	2	2
5	Capability to expand model and/or potentially merge with MWDOC member agency models in the future	Ability to merge models of the same software format?	Yes; Merge Model Tool can be used to merge multiple InfoWater models	2	6	Partially. Submodel manager can merge some functionality of models.	1	3	Yes; Submodel Import Tool can be used to merge multiple WaterGEMS models	2	6
		Ability to merge models of different software formats?	Partially; Model would need to be converted via EPANet into InfoWater before merging	1	2	Partially; Model would need to be converted via EPANet into Mike Urban before merging	1	2	Partially; Model would need to be converted via EPANet into WaterGEMS before merging	1	2

No.	MWDOC Needs/Goals	Software Capability Criteria	InfoWater			MIKE Urban			WaterGEMS		
			Functionality Description	***Score***	***Weighted Score***	***Functionality Description***	***Score***	***Weighted Score***	***Functionality Description***	***Score***	***Weighted Score***
6	Easy to use and reference model results (i.e. tabular, graphical, GIS compatibility)	Ability to efficiently display results graphically and in an easy to understand manner?	Yes	2	4	Yes	2	4	Yes	2	4
		Ability to export results to GIS, Excel, PowerBI, and other external data analysis is and visualization tools?	Yes, able to export shapefiles with data or export results to excel	2	4	Yes, able to export shapefiles with data	2	4	Yes; able to export model to excel file and shapefiles	2	4
7	Model scenario manager capable of storing many hydraulic and/or water quality runs over time	Ability to develop and manage multiple model scenarios?	Yes	2	4	Yes	2	4	Yes	2	4
8	Capability to track history of edits to model input data and model runs/scenarios	Ability to track changes to physical model data?	No, "track changes" not available. However, data flagging can be conducted	1	1	No, "track changes" not available. However, data flagging can be conducted	1	1	Yes, change tracking can be enabled/ disabled	2	2
		Ability to track changes to input parameters from scenario to scenario?	No "track changes". But can use tool to compare data between scenarios to find unintentional differences	1	1	No	0	0	Yes, able to conduct scenario to scenario comparison	2	2
9	Simulation of system water quality	Ability to perform source trace simulations?	Yes. Source trace simulations available	2	6	Yes. Source trace simulations available	2	6	Yes. Source trace simulations available	2	6
		Ability to perform water age simulation?	Yes, water age simulations available	2	6	Yes, water age simulations available	2	6	Yes, water age simulations available	2	6
		Ability to perform water quality constituent simulations?	Yes; MSX extension available which models complex reactions b/w multiple chemical and biological species	3	6	Yes; single constituent analysis available	2	4	Yes, Multi Species Extension for advanced WQ modeling	3	6
Technical Score Results			**70**			**65**			**72**		

Additional Software Evaluation Criteria											
No.	***MWDOC Need/Goal***	***Criteria***	***InfoWater***			***MIKE Urban***			***WaterGEMS***		
10	Prevalence in Orange County	Water utilities and agencies using the software for water system modeling?	Used by ETWD, San Clemente, LBCWD SCWD, and TCWD	3	9	MWD	1	3	N/A - Not used by nearby Utilities	0	0
11	License Cost	For comparison purposes, cost of unlimited pipe software license with any additional modules/add-ons that may be needed to meet MWDOC's above Needs/Goals?	InfoWater: $17,000-21,000; InfoWater Pro: $20,000-28,000; Floating License is 50% of fixed software cost	2	4	12-month subscription license is $5,540; perpetual license is $8,400	3	6	$ 30,801	1	2
12	Annual Maintenance Cost	Annual cost of software maintenance including version upgrades and technical support supplied by vendor for above software license?	20% of fixed software cost (~$4000)	2	4	Price included for year 1; $1,520 for year 2 and onwards	3	6	$ 7,392	1	2
13	Technical Support	Location of technical support staff?	US, Australia, and the UK	2	4	Main US office - Colorado; numerous offices worldwide	2	4	Main US Office - Pennsylvania; numerous offices worldwide	2	4
		Working hours and days of week of technical support staff?	24 hours a day (gap on weekends) can get an engineer on the phone	3	6	Tech support available	2	4	Tech support available	2	4
Overall Score Results			**97**			**88**			**84**		

Software Market Survey Results and Selection Decision Support Tool

No.	*MWDOC Needs/Goals*	*Software Capability Criteria*	*EPANet*			*InfoWorks ICM*			*InfoWorks WS*		
			Functionality Description	*Score*	*Weighted Score*	*Functionality Description*	*Score*	*Weighted Score*	*Functionality Description*	*Score*	*Weighted Score*
1	Simulation of full-pipe pressurized flow conditions which normally exist in most areas of MWDOC's system, as well as, partially-full unpressurized flow conditions in some areas of the system (i.e. Santiago Lateral)	Ability to perform pressurized flow hydraulics?	Yes	2	6	Yes, but primary intended for gravity collection system hydraulics.	1	3	Yes	2	6
		Ability to perform or represent open channel flow hydraulics?	No, not intended to model open channels	0	0	InfoWorks ICM SE can model watercourses, open channels and stormwater structures	2	2	Yes; Ability to model open channels using time dependent equations	1	1
2	Simulation of steady-state, time-varying (dynamic or extended period simulation (EPS)), and transient (surge) hydraulic conditions	Ability to perform steady-state hydraulics?	Yes	2	6	Yes	2	6	Yes	2	6
		Ability to perform time-varying hydraulics?	Yes	2	6	Yes	2	6	Yes	2	6
		Ability to perform transient hydraulics?	No	0	0	No; not intended for water distribution transient analysis	0	0	Yes; InfoWorks WS Pro includes transient/surge analysis	2	4
3	Hydraulic simulation of treatment plant supplies, pumping stations, storage facilities, pressure/flow regulating stations, and demand/flow transfer points	Ability to simulate same?	Yes	2	6	Yes	2	6	Yes	2	6
4	Compatibility with MET's Mike Urban model and/or ability to import model data to support model build	Ability to import Mike Urban models and/or GIS data exported from Mike Urban?	Mike Urban model can be converted to EPANet using data converter (EPANET 2.0 Bridge)	2	2	Yes; able to import GIS shapefiles exported from a Mike Urban model	2	2	Yes; able to import GIS shapefiles exported from a Mike Urban model	2	2
		Ability to import EPANet models exported from Mike Urban?	Yes; able to import .inp (EPANet) files	3	3	Not intended for water distribution. Could import SWMM files probably.	0	0	Yes; able to import .inp (EPANet) files	2	2
5	Capability to expand model and/or potentially merge with MWDOC member agency models in the future	Ability to merge models of the same software format?	No; cannot merge models	0	0	No	0	0	Yes; Merge Model Tool can be used to merge multiple InfoWater models	2	6
		Ability to merge models of different software formats?	No; cannot merge models	0	0	No	0	0	Partially; Model would need to be converted via EPANet into InfoWorks WS before merging	1	2

No.	***MWDOC Needs/Goals***	***Software Capability Criteria***	***EPANet***			***InfoWorks ICM***			***InfoWorks WS***		
			Functionality Description	***Score***	***Weighted Score***	***Functionality Description***	***Score***	***Weighted Score***	***Functionality Description***	***Score***	***Weighted Score***
6	Easy to use and reference model results (i.e. tabular, graphical, GIS compatibility)	Ability to efficiently display results graphically and in an easy to understand manner?	Partially, visually limited compared to other software	1	2	Yes	2	4	Yes	2	4
		Ability to export results to GIS, Excel, PowerBI, and other external data analysis is and visualization tools?	Partially. Can copy and paste results to excel	1	2	Yes; able to export model to excel file and shapefiles	2	4	Yes; able to export model to excel file and shapefiles	2	4
7	Model scenario manager capable of storing many hydraulic and/or water quality runs over time	Ability to develop and manage multiple model scenarios?	No; no model scenario manager	0	0	Yes	2	4	Yes	2	4
8	Capability to track history of edits to model input data and model runs/scenarios	Ability to track changes to physical model data?	No	0	0	Yes	2	2	Yes. Model objects are version controlled and commit history keeps track of changes	2	2
		Ability to track changes to input parameters from scenario to scenario?	No	0	0	Yes	2	2	Yes. Model objects are version controlled and commit history keeps track of changes	2	2
9	Simulation of system water quality	Ability to perform source trace simulations?	Yes; non-reactive tracer material	2	6	Yes. Source trace simulations available	2	6	Yes. Source trace simulations available	2	6
		Ability to perform water age simulation?	Yes, water age simulations available	2	6	Yes, water age simulations available	2	6	Yes, water age simulations available	2	6
		Ability to perform water quality constituent simulations?	Yes, movement and fate of a reactive material as it grows or decays with time; MSX extension	3	6	Yes, water quality simulations available	2	4	Yes, water quality simulations available	2	4
Technical Score Results			**51**			**57**			**73**		

Additional Software Evaluation Criteria

No.	***MWDOC Need/Goal***	***Criteria***	***EPANet***			***InfoWorks ICM***			***InfoWorks WS***		
10	Prevalence in Orange County	Water utilities and agencies using the software for water system modeling?	LBCWD	1	3	N/A - Not used by nearby Utilities	0	0	N/A - Not used by nearby Utilities	0	0
11	License Cost	For comparison purposes, cost of unlimited pipe software license with any additional modules/add-ons that may be needed to meet MWDOC's above Needs/Goals?	Free	3	6	$50,000-60,000; License is 50% of fixed software cost	0	0	WS Pro: $31,000; Floating License is 50% of fixed software cost	1	2
12	Annual Maintenance Cost	Annual cost of software maintenance including version upgrades and technical support supplied by vendor for above software license?	Free	3	6	20% of fixed software cost	0	0	20% of fixed software cost	1	2
13	Technical Support	Location of technical support staff?	No technical support	0	0	US, Australia, and the UK	2	4	US, Australia, and the UK	2	4
		Working hours and days of week of technical support staff?	N/A	0	0	24 hours a day (gap on weekends) can get an engineer on the phone	3	6	24 hours a day (gap on weekends) can get an engineer on the phone	3	6
Overall Score Results			**66**			**67**			**87**		

Software Market Survey Results and Selection Decision Support Tool

No.	***MWDOC Needs/Goals***	***Software Capability Criteria***	***KYPipe***			***Synergi Water***			***Preliminary Weight Factor***
			Functionality Description	***Score***	***Weighted Score***	***Functionality Description***	***Score***	***Weighted Score***	
1	Simulation of full-pipe pressurized flow conditions which normally exist in most areas of MWDOC's system, as well as, partially-full unpressurized flow conditions in some	Ability to perform pressurized flow hydraulics?	Yes	2	6	Yes	2	6	**3**
		Ability to perform or represent open channel flow hydraulics?	No	0	0	Yes. With the new release of DNV GL's Synergi Water, closed pipe networks and open channel flow in steady state can be modelled directly within the same software	1	1	**1**
2	Simulation of steady-state, time-varying (dynamic or extended period simulation (EPS)), and transient (surge) hydraulic conditions	Ability to perform steady-state hydraulics?	Yes	2	6	Yes	2	6	**3**
		Ability to perform time-varying hydraulics?	Yes	2	6	Yes	2	6	**3**
		Ability to perform transient hydraulics?	No, Surge module is needed as a compatible software from KYPipe to conduct transient analysis	1	2	Yes; LIQT Module in Synergi Water is available for water hammer analysis	2	4	**2**
3	Hydraulic simulation of treatment plant supplies, pumping stations, storage facilities, pressure/flow	Ability to simulate same?	Yes; models various types of valves, different shape storage tanks, multiple demand types at nodes, control elements based on conditions	2	6	Yes	2	6	**3**
4	Compatibility with MET's Mike Urban model and/or ability to import model data to support model build	Ability to import Mike Urban models and/or GIS data exported from Mike Urban?	Yes, KYPipe2020 imports shape files; must be shp, shx, and dbf	2	2	Yes; Model Builder module allows for integration with GIS data	2	2	**1**
		Ability to import EPANet models exported from Mike Urban?	Yes; able to import .inp (EPANet) files	2	2	Yes; able to import .inp (EPANet) files	2	2	**1**
5	Capability to expand model and/or potentially merge with MWDOC member agency models in the future	Ability to merge models of the same software format?	No	0	0	Yes; Subsystem Management Module can be used	2	6	**3**
		Ability to merge models of different software formats?	No	0	0	Partially; Model would need to be converted via EPANet into Synergi before merging	1	2	**2**

No.	***MWDOC Needs/Goals***	***Software Capability Criteria***	***KYPipe***			***Synergi Water***			***Preliminary Weight Factor***
			Functionality Description	***Score***	***Weighted Score***	***Functionality Description***	***Score***	***Weighted Score***	
6	Easy to use and reference model results (i.e. tabular, graphical, GIS compatibility)	Ability to efficiently display results graphically and in an easy to understand manner?	Yes	2	4	Yes	2	4	**2**
		Ability to export results to GIS, Excel, PowerBI, and other external data analysis is and visualization tools?	Yes; Can Export Excel, AutoCAD and GIS Files	2	4	Yes. Can export to ESRI data format like Shapefile and Geodatabase; also excel	2	4	**2**
7	Model scenario manager capable of storing many hydraulic and/or water quality runs over time	Ability to develop and manage multiple model scenarios?	Yes	2	4	No; old tool for scenario management but is not used much	0	0	**2**
8	Capability to track history of edits to model input data and model runs/scenarios	Ability to track changes to physical model data?	No, "track changes" not available. However, data flagging can be conducted	1	1	No, nothing built-in. "Custom Attributes" and "Service State" can be used	1	1	**1**
		Ability to track changes to input parameters from scenario to scenario?	No	0	0	No, nothing built-in. "Custom Attributes" and "Service State" can be used	1	1	**1**
9	Simulation of system water quality	Ability to perform source trace simulations?	Yes. Source trace simulations available	2	6	Yes. Source trace simulations available	2	6	**3**
		Ability to perform water age simulation?	Yes, water age simulations available	2	6	Yes, water age simulations available	2	6	**3**
		Ability to perform water quality constituent simulations?	Yes, water quality simulations available	2	4	Yes, Multi Species Extension for advanced WQ modeling	3	6	**2**
Technical Score Results			**59**			**69**			**69**

Additional Software Evaluation Criteria

No.	***MWDOC Need/Goal***	***Criteria***	***KY Pipe***			***Synergi Water***			***Weight Factor***
10	Prevalence in Orange County	Water utilities and agencies using the software for water system modeling?	N/A - Not used by nearby Utilities	0	0	N/A - Not used by nearby Utilities	0	0	**3**
11	License Cost	For comparison purposes, cost of unlimited pipe software license with any additional modules/add-ons that may be needed to meet MWDOC's above Needs/Goals?	Around 50,000-pipe perpetual license is around $30,000/annual subscription is around $10,000	2	4	$15,836; includes maintenance and support fee	2	4	**2**
12	Annual Maintenance Cost	Annual cost of software maintenance including version upgrades and technical support supplied by vendor for above software license?	Maintenance included in yearly annual subscription; perpetual licensing maintenance is not required	3	6	See above	3	6	**2**
13	Technical Support	Location of technical support staff?	Eastern Time Zone	1	2	A couple US locations	2	4	**2**
		Working hours and days of week of technical support staff?	May contact at anytime; response can be expected within a day	2	4	Tech Support Available	2	4	**2**
Overall Score Results			**75**			**87**			