Ditch System Sustainability Project

OPERATION AND MAINTENANCE STRATEGIES FOR REDUCING NON-CONSUMPTIVE USE WATER




February 2012

Submitted by
Stantec Consulting Services Inc.

Stantec

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Tuolumne Utilities District
Ditch System Sustainability Project
Operation and Maintenance
Strategies for Reducing Non-Consumptive Use Water

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February 2012

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1.0 Introduction and Background

The Tuolumne Utilities District (District) owns and operates the ditch system to supply raw water to customers for consumptive use. Consumptive use includes agricultural, individual domestic use directly from the ditch, municipal, commercial, and industrial uses within its service area, and is defined as MI&A for the purpose of this report. Raw water from Lyons Reservoir is conveyed through the Main Canal which is owned and operated by the Pacific Gas & Electric Company (PG&E), from which the District's ditches are supplied raw water. The District's raw water system is comprised of a complex series of ditches, pipelines, flumes, and storage reservoirs to convey water through the system. Figure 1 includes a map that shows the overall ditch system and the District boundary.

The District has an existing contract with PG&E that stipulates the amount of water the District can divert and the specific location of the diversions. The District typically diverts approximately 17,500 acre-feet annually. A portion of the water is sold to MI&A customers and generates revenue. The non-revenue generating water, or the non-consumptive use component, represents water that is diverted into the District's system and is released through various means, including seepage and end releases, and is not sold to customers. The non-consumptive use component provides ecosystem enhancement within in the District's service area, the extent of which was not quantified in this study.

The District desires to identify Operation and Maintenance (O&M) Strategies that could reduce the non-consumptive use component within the system to some extent, and would free up more water for MI&A uses if necessary. The District recognizes the benefit that the non-consumptive use component of its water supply provides to the local ecology and hydrology. Proposed O&M strategies to reduce the non-consumptive use component will include a combination of O&M related activities and improvements implemented through the Capital Improvement Program (CIP), which is being completed concurrently.

2.0 Purpose and Objectives

The primary purposes of this memorandum are to develop O&M Strategies that could be used to reduce the non-consumptive use component of the District's water supply, and to identify potential enhancements to the ecosystem and hydrology in the area that results from release of the water. In order to accomplish these objectives, the following approach was taken:

- Estimation of non-consumptive use component – field investigations to identify sources of the non-consumptive use and quantification are not included in the scope of this project. However, the District has completed historical studies to estimate the non-consumptive use component which are summarized herein
- Identify potential means to reduce the non-consumptive use component through CIP projects and O&M activities
- Develop a strategy and implementation plan
- Qualitatively identify potential enhancements to the local ecology and hydrology resulting from the release of the non-consumptive use component to the surrounding area.

3.0 Fate of Non-Consumptive Use Water

Water that is not used for MI&A uses is considered to be the non-consumptive use component. Non-consumptive use water is released from the raw water system and has the potential to enhance the ecosystem and local hydrology. Examples of utilizing the raw water for ecosystem benefits is included in the Mitigation Banking, Oak Tree section of the Case Studies as well as the Capital Improvement Program prepared as part of this project.

Use of raw water for preservation and enhancement of fish and wildlife resources is considered a beneficial use of water in the California Water Code Section 1243. Key Vision Statements from the District's 2008 Strategic Plan related to the balance between water supply and ecosystem enhancements are listed below:

- Maximize available water supplies and secure additional supplies to meet current and future needs
- Practice environmental stewardship for multiple benefits and protect our resources
- Cooperate with strategic partners to protect regional water resources for the people we serve

The non-consumptive use component of the District's water supply provides a number of potential benefits. The extent of these benefits was not determined in this study. Benefits include:

- Potential creation of wetlands and riparian areas
- Aesthetic enhancement
- Groundwater recharge (extent unknown)
- Evaporative cooling
- Creation of habitat for various flora and biota in the vicinity of the ditches

Practicing environmental stewardship utilizing raw water for ecosystem enhancement is consistent with State law and policy. The District has an obligation to provide a reliable water supply to its customers, and meeting current and future MI&A water needs could at times represent a conflicting goal with environmental enhancement related to non-consumptive water releases in the system, particularly during critical dry periods when water supply is short.

The District should quantify the non-consumptive use component of the water supply utilizing the new flow metering stations discussed herein. Once the non-consumptive use component is quantified, the Board can determine from a policy level the appropriate balance of MI&A uses, compared to the ecosystem benefits derived as a result of the non-consumptive component that leaves the system. Targeting specific high value ecosystem enhancements within the ditch system may be a means by which the available water supply can meet both the goals.

4.0 Historical Evaluations

The most comprehensive study to date to estimate the non-consumptive use component within the ditch system was performed in 2003 as part of the "Tuolumne Utilities District Ditch Optimization Plan – Water Balance Study", prepared by EIP Associates (2003). A water balance was developed to account for the known/estimated water entering the system and the known/estimated water leaving the system. By quantifying these "known" input and outputs, summarized in Table 1, the estimated non-consumptive use was calculated for each ditch on an individual basis and from an overall perspective. Flow data used in the study were based on estimated use of a limited number of gauging stations and installation of temporary gauging stations.

Table 1
Water Balance Variables

Water In	Water Out
Inflow to ditch head	Customer use
Precipitation onto water surfaces[(a)]	Evaporation from ditch and reservoir surfaces
Runoff entering the ditches and reservoirs[(a)]	End releases from terminal ditches
Water In – Water Out =	Non-Consumptive Use (seepage, leaks, theft, evapotranspiration)

(a) The 2003 water balance was completed during dry weather to eliminate these sources of water into the ditch system.

Results of the study indicated that the non-consumptive use, primarily consisting of seepage, ranged between 2 to 83-percent on an individual ditch basis. Figure 2 includes a graphic representation of the results from that study that shows the estimated non-consumptive use component in the individual ditches at that time. The overall non-consumptive use component was estimated to be approximately 47-percent in that study.

Many ditch systems operate at roughly the same efficiency. Since 2003, the District has continued to implement projects, including installation of gunite liners to improve system reliability, and to reduce system operations costs and the non-consumptive use component. To date, over half of the ditch system has been lined with gunite, and the overall non-consumptive use component is likely less than that estimated in 2003. An ongoing project to install flow monitoring stations is described later in this report and will be used to collect flow data necessary to quantify system flows.

5.0 Non-Consumptive Components Considered

The non-consumptive use components must be identified and ranked relative to one another in order to understand their magnitude, and make a determination whether or not efforts should be made to reduce or eliminate them. Potentially large non-consumptive use components that should be addressed as part of the O&M Strategy are described below. Identifying these sources, quantifying them, determining their value, and modifying operations and/or implementing a CIP related improvement if desired, will be keys to reducing the non-consumptive use component to increase water available for MI&A uses.

- *Seepage* – Seepage is water that “seeps” or percolates from the ditch through the bottom and sides of the ditch into the underlying soils. Seepage volumes can be high depending on soil permeability and whether the ditch is piped, partially or fully lined, or unlined. Piped and lined ditches generally have lower seepage rates than partially or unlined sections.

- *Leakage* – Leakage occurs at specific points and is more easily preventable than seepage. Leakage occurs through animal burrows or damaged ditch embankments, gates, and other flow control structures that may allow water to escape the channel. Leakage can also occur in piped sections. Water leaving the system through leaks is adsorbed into the soil, or flows to natural waterways and drainage courses.

- *Operational Releases* – Operational releases result from design or operational characteristics of the ditch system. District operations and engineering staff work to optimize system operation by moderating system flows to prevent spills or releases at the terminus of each ditch. Where excess water in the ditch exceeds demand, it overflows at spill structures and is released from the system. Water released from ditch terminuses flows into drainages and natural waterways.

The sources listed above have the potential to represent large sources of the non-consumptive use component in the system; the non-consumptive use components listed below should be considered, but are generally relatively small in comparison those listed above.

- *Evaporation* – Evaporation is present, although on the ditch system is relatively minor compared to other non-consumptive use components. Generally speaking slow, wide and shallow ditches are more susceptible to evaporative than deeper faster moving ditches. Evaporation from reservoirs is difficult to control and must be budgeted for in the overall system water balance.

- *Adsorption* – Adsorption occurs when ditches are cycled between wet and dry conditions. The dry soil within the wetted ditch perimeter adsorbs water each time the ditch is refilled. In the District's case, most of the ditches are flowing almost all the time unless there is an outage, and adsorption is not significant.

- *Theft* – Unauthorized use of water is certainly present, but is a relatively small component of non-consumptive uses. Ditch system operators actively seek out and eliminate illegal diversion of raw water as part of their everyday activities.

- *Evapotranspiration* – Is considered the water taken up by vegetation and released to the atmosphere. Ditches with heavy vegetation present in bottom and slopes of the ditch embankment will have a higher evapotranspiration rate than those with minimal vegetation. This component is considered to relatively low and difficult to control.

- *Randoms* – Randoms are natural water courses in the system used to convey raw water from one portion of the ditch system to another. There are approximately 19,500 feet of randoms within the ditch system. Substrates in these areas vary from sandy gravels to fractured rock. Seepage through the randoms could be relatively high, but no measurements are available to confirm this. Lining or piping these segments would reduce the amount of seepage; however, there would be substantial impact to riparian zones within the watercourse.

6.0 Strategy and Approach

A strategy is developed in this section to identify and reduce non-consumptive use components of the water supply. The approach includes three interrelated strategies that include:

- Monitor flows to identify areas of the system with disproportionally high levels of non-consumptive use
- Prioritize sources contributing to non-consumptive use and make a determination whether effort should be made to reduce or eliminate the source
- Implement means and methods to eliminate or reduce sources of non-consumptive use through capital projects or operation and maintenance activities

6.1 FLOW MONITORING PROGRAM

An effective flow monitoring program is imperative to identify, quantify, and reduce or eliminate sources of non-consumptive use in the system. Without accurate information, the District cannot identify and prioritize critical areas, nor will it be possible to measure the effectiveness of operational procedures and physical improvements. Both permanent and temporary flow monitoring are recommended.

Permanent Flow Monitoring Network. The District has recognized the need to measure flows in the system and applied for and received funding to install 24 flow meters throughout the ditch system through a Proposition 50 grant. The flow monitoring stations will provide information related to operations and system efficiency including:

- Early warning in the event of a problem in the system such as failure of a ditch, flume, or pipeline that may interrupt flow
- Locate illegal diversions in the system
- Allow operations staff to optimize system flow
- Provide insight into areas of the system with proportionally higher sources of non-consumptive use

Eighteen of the stations have been installed, and the remaining six will be installed later this year. The new flow monitoring stations consist of a Parshall flume with a staff gauge which is currently manually read for an instantaneous flow reading, but will be equipped with automated instrumentation that reads, stores, and transmits the data. Parshall flumes are commonly used to measure open channel flow when debris such as sticks, vegetation, and sediment are present because they tend to be self-cleaning due to their design. The locations of the new flumes are identified in Figure 3.

Once the automated data collection instrumentation is installed on the new flumes, the flow data will be collected nearly continuously, and sent by way of a radio system, back to the District's Supervisory Control and Data Acquisition (SCADA) central location. Continuous flow monitoring will enable the District to monitor flow into and out of the various ditch reaches. Sources of non-consumptive use throughout the reach can be estimated, as well as an estimation of how much water is gained, which is also important to monitor during runoff events associated with rainfall or snowmelt. Too much water can damage the ditches and other appurtenances resulting in an uncontrolled overflow that can damage the ditch embankments as well as property below the ditch.

Each new installation should be calibrated to confirm that the device is operating properly and providing accurate readings. Accuracy of each site should also be checked periodically by ditch operators to ensure accurate data is being collected. Typical problems that can affect accuracy include:

- Accumulation of debris (e.g. sediment, vegetation, etc.) within the flume, or immediately upstream or downstream of the flume that affect the water level
- Changes to the approach to the flume, or discharge from the flume that may impact the flow path and alter the water level
- Settlement of the entire flume that will affect hydraulics
- Drift in the accuracy of electronics of the level sensor

Often these types of issues occur gradually over time and may not be noticed, so regular calibration and/or confirmation is important, the frequency of which will be site specific.

Additional locations for permanent stations may be desired for operational or monitoring purposes once the flow program is initiated and data is analyzed. Future locations may include monitoring stations located at or near spills, or on areas of the ditches that have a large influx of runoff entering them, such as Table Mountain or the Algerine.

Temporary Flow Monitoring. The distances between the flumes shown on Figure 3 vary. In some cases, the distance between the monitoring stations is too large to accurately identify specific problematic reaches where sources of non-consumptive use are abnormally high and should be evaluated on a case by case basis. The additional information may be used to identify specific sections of the ditches to line with gunite.

Temporary flow monitoring can be accomplished using a variety of methods depending on location and duration of the installation. Instrumentation to measure flow, velocity, and level is readily available and can be purchased or rented. Most of these systems have the capability to accumulate and store the information until it is retrieved; remote monitoring and/or transfer of data using radio is also possible, but will be site specific.

Existing facilities can also be used as temporary flow monitoring stations with minor modifications that will not impact raw water conveyance to customers. Existing spills are a good example where temporary weirs can be installed and instrumentation used to monitor level over the check boards acting as a weir. Temporary weirs can also be constructed easily within the ditch without the use of concrete or other permanent material. Care should be taken to ensure that the temporary installations are providing accurate data. Use of velocity probes and the cross sectional area of the ditch to calculate instantaneous flow is one method to spot check the accuracy.

6.2 REDUCTION OF NON-CONSUMPTIVE USE SOURCES

Means to reduce sources of non-consumptive use through implementation of projects are considered below with specific recommendations.

Seepage. Seepage results as water percolates through the bottom and sides of the ditch. Seepage rates vary depending on a number of factors. Some of the key parameters that affect seepage rates in the ditches include:

- Lined vs. unlined
- Underlying soil type (particularly for unlined ditches)
- Slope
- Depth of water in the ditch
- Groundwater table relative to ditch invert
- Ditch geometry

Soil types vary considerably within the District's service area. The United States Department of Agriculture's National Resource Conservation Service administers the National Cooperative Soil Survey (NCSS). The NCSS collects soil information throughout the country. Soil characteristics, such as soil type, permeability, composition, etc., are the most important variables related to seepage rates from the ditches. NCSS has not published soil types within Tuolumne County at this time, so no system wide correlation could be made, but based on the field survey work completed as part of this project there are variations in soils throughout the system and as a result, some of the ditches, such as Table Mountain and the Algerine are known to have high seepage rates.

Figure 4 includes a graph of typical seepage rates in various types of soils. Soils with a lot of sand and gravel typically have high seepage rates, whereas clayey soils tend to reduce seepage. As shown there is almost a tenfold reduction in seepage rates between sandy and clayey soils. Concrete linings tend to reduce seepage by greater than a factor of 10 compared to unlined ditches in a loam or sandy loam. It is also common in Sierra Foothills settings for fractured rock underlying ditches to contribute significantly to seepage. However, the permeability of fractured rock is not uniform and needs to be addressed on a case by case basis.

The District generally applies gunite to approximately one to two miles of ditch each year. Gunite lining serves at least six main purposes within the ditch system: (1) preventing erosion of the ditch embankment and scouring of the bottom, 2) reducing seepage and leakage that results in diminished structural integrity that could lead to failure; (3) reinforcing the embankments to preserve the shape and location of the original earthen berm; (4) increasing the ditch reliability; (5) reducing the ongoing operation and maintenance efforts and cost by reducing vegetative growth, reducing potential for leaks, and increasing the structural integrity of the ditch; and (6) reduces the amount of time the ditch may be out of service for maintenance.

Historical use of gunite in the ditches has been deemed an activity that does not diminish the historical integrity of the ditch system. More information related to gunite application is included in the Historical Properties Management Plan (HPMP).

Use of gunite is considered the most cost effective means to reduce seepage within the system and has other advantages as discussed above. Historically, gunite has been applied with an approximate thickness of one to three inches, with steel mesh used to reinforce the concrete material to attempt to minimize cracking. However, completely preventing cracks is not cost effective or reasonably possible. As cracks develop, they may result in an increased permeability of the lining, the extent of which is unknown as sediment and other naturally occurring materials likely accumulate in the crack and reseal it.

Application of a flexible plastic liner may provide additional long term sealing properties. The addition of the plastic liner may be difficult to install, and in some cases could reduce the structural integrity of the gunite liner if voids form between native material and the gunite. A small section of the Algerine was lined with a flexible plastic liner under the gunite but its performance was never evaluated. Evaluation of the sealing properties of aged gunite liners may provide additional information. If cracking does significantly increase seepage rates in unlined gunite, a pilot study to assess the effect of using a plastic liner should be conducted in one or more of the ditches prior to widespread implementation.

Amending the soil underlining the ditch with clayey material has been used successfully on larger ditches. Equipment necessary to mix and compact the clay/native soil is large and must impart a lot of mixing and compacting energy to be effective. Ditches in the system are too small for this type of equipment, so use of clay in the District's is not considered a viable alternative.

There is speculation that eliminating or reducing the seepage may have an impact to vegetation, particularly trees in along the ditch corridor. An evaluation of any potential impacts is beyond the scope of this report; however, consideration of the possible effects should be considered when selecting areas of the ditch system that will be lined, piped, or re-routed and could result in a potential change to the localized hydrology. Partial lining of the ditch cross section, limited to the outer embankment, where erosion occurs may be an alternative method to protect the ditch integrity in potentially tree sensitive areas. An evaluation of the potential impact on ditch lining to oak trees is included in the Oak Tree case study prepared as part of this project.

End Releases. End releases occur at the ditch terminus when there is no consecutive downstream ditch receiving the released water. End releases are almost impossible to completely eliminate. In order to ensure that adequate water reaches customers at the end of the ditch, operators must put excess water in at the head of the ditch – without the adequate water, customers at the end of the ditch may not receive water, which is not acceptable.

End releases flow into drainages and natural water courses. End releases occur at the end of the following ditches in the District's system:

- Matelot
- Montezuma
- Algerine
- Roaches Camp
- San Diego

Potential means to reduce or eliminate end releases are discussed below.

Matelot – The Matelot Ditch is fed from the Matelot Reservoir which is directly downstream of and supplied from the Columbia Ditch. The Matelot Reservoir provides an equalizing effect: when the flow into the reservoir is less than the flow out, the reservoir drops and vice versa. The Reservoir is shown in Photo 1. Ditch operators manually monitor the level and make adjustments to the raw water flow at the head of the Columbia Ditch as needed. The District's Columbia Water Treatment Plant (WTP) intake is approximately 1,500 feet downstream of the Matelot Reservoir, and represents the largest single demand on the Matelot Ditch. The Columbia WTP treats approximately 900 gpm during the summer. Treatment plant operations staff attempts to operate the plant at a constant rate utilizing storage to minimize starting and stopping the plant.

When offline, there is no water diverted to the Columbia WTP. Raw water flows past the diversion point to the end of the Matelot Ditch. The Matelot transitions from open channel to pipe at Spill 3; excess water in the ditch at the pipe transition spills to a drainage and is not recoverable and is shown in Photo 2. In order to avoid this situation, a new pipeline from the Matelot Reservoir directly to the WTP should be installed.

Constructing a dedicated pipeline from the Matelot Reservoir to the WTP would eliminate the large flow variations in the ditch and reduce or eliminate the release at Spill 3, which is the largest single source of non-consumptive use on the ditch. Approximately 1,500 feet of pipe and hydraulic controls would be needed. A flow control valve located at the turnout would be used to control flow into the water treatment plant. The reservoir level would vary and provide equalization that would allow operations staff to vary the upstream flows. Level sensors and remote monitoring of the reservoir would simplify operations.

Water quality to the water treatment plant would be improved during runoff events as an added benifit. When the water in the ditch becomes turbid due to runoff carrying contaminants into the ditch, the undesired water could be bypassed around the Matelot Reservoir until it cleared up. During the bypass, water would be diverted from the relatively clean reservoir directly to the Columbia WTP through the new pipeline. The reservoir would provide temporary storage, and then be refilled when the ditch water cleaned up and was rediverted through the reservoir.

Proposed improvements and operation strategies include:

- Dedicated pipe from Matelot Reservoir to Columbia WTP
- Flow control structure at the Columbia WTP
- Automated level monitoring at the Matelot Reservoir

This project has been included in the CIP.

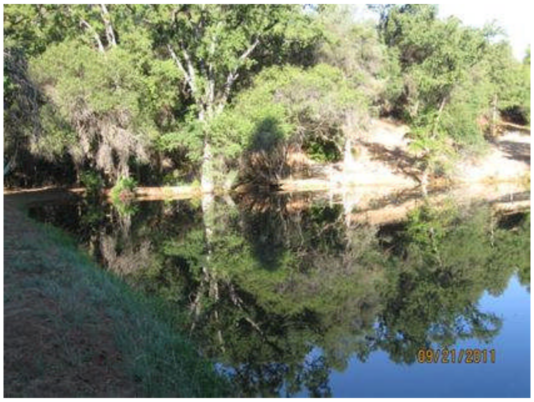


Photo 1
Matelot Reservoir

Photo 2
End of Matelot at Spill 3

Montezuma – The Montezuma Ditch transitions from open channel ditch to a pipe in the vicinity of Pulpit Rock Road, just east of the mine site. The raw water passes over a perforated screen to prevent debris from entering the pipeline. Demands along the pipeline vary; when customers are not using water from the pipe, the raw water overflows to the southeast towards Highway 108 and leaves the ditch system. Excess flow must be maintained at this location to ensure that there is adequate water to fill the pipe.

The release at this location was substantial during the field investigations conducted in September 2011 as shown in Photo 3. An equalizing reservoir would reduce the end release by providing a location to store the water. The level of the reservoir would fall when demands into the pipe exceeded the flow into the reservoir. Conversely, the level would rise when inflow exceeded demands from the pipeline. Automated monitoring of the reservoir would provide operations staff real time information to use for adjusting flow into the ditch.

Proposed improvements and operation strategies include:

- Construction of a small reservoir at the end of the ditch
- Automated level monitoring of the reservoir

This project has been included in the CIP.

Photo 3
End Release at End of Montezuma at Spill 2

Algerine – The Algerine is one of the District's longest ditches and currently serves only 21 customers. The majority of the ditch is unlined. Due to soil conditions, seepage in the ditch is high, and there was an abundance of vegetative growth present. District operations staff must add excess water at the head of the ditch to ensure water is available to customers at the end of the ditch. End release at the end of the Algerine was minimal during field studies conducted in September 2011. Blue Gulch, the terminal reservoir of the Algerine, is shown in Photo 4. The addition of a level sensor is recommended to monitor and quantify releases at the end of the ditch; however, due to the small number of customers, long length of ditch and high seepage rates, trying to match flow at the top of the ditch to match customer use will be difficult.

Proposed Improvements and operation strategies include:

- Level monitoring of the reservoir

Photo 4
Blue Gulch Reservoir at end of Algerine

Roaches Camp – The Roaches Camp Ditch receives water from the Eureka Ditch. The Roaches Camp Ditch services 42 agricultural customers. Two of the larger agricultural users are near the end of the ditch; therefore ditch operators must supply enough water to ensure water availability for the customers. Currently, avoiding or minimizing the end release on the Roaches Ditch requires careful coordination and monitoring of the flows, and even then releases occur or there is insufficient water available.

The Wiber-Armstrong Ponds consist of two small reservoirs which are shown in Photos 5 and 6 below and are about 2,000 feet from the end of the ditch. The large agricultural users are located between the ponds and the end of the ditch. The ponds could be used to supply water to the users downstream via a dedicated pipeline. Water level would fluctuate in the ponds and provide equalization and prevent most of the current end release, which is currently utilized by non-paying customers downstream of the ditch terminus. The District would need to discuss the improvements with the land owners and raw water customers.

Proposed Improvements and operations strategies include:

- Proceed with negotiations with the land owners to utilize the ponds
- Construct dedicated pipelines to downstream raw water customers
- Install level monitoring instruments in the ponds to adjust flows

Photo 5
End Release on Roaches Camp Ditch

Photo 6
Wiber-Armstrong Reservoir

San Diego – The San Diego Ditch is one of the smaller ditches in the system serving roughly 70 agricultural customers. Although the ditch has a rated capacity of 4 cfs, it is generally operated at about 2 cfs. Spill #1 is located at the end of the ditch. During field investigations in September 2011 the end release observed was minimal as shown in Photo 7, and the potential end release at this location is considered to be minor in comparison with other ditches in the system. One possible improvement would utilize the small pond for flow equalization, and install a small pump to lift water to feed a small private ditch which extends beyond the District's ditch.

A potential means to reduce or eliminate the end release could be to install a pump to lift water and feed the small private ditch that extends beyond the spill and end of the District maintained facilities. Operation and maintenance costs would need to be considered to determine the cost effectiveness of the improvements.

Proposed Improvements and operations strategies include:

- None related to end releases at this time

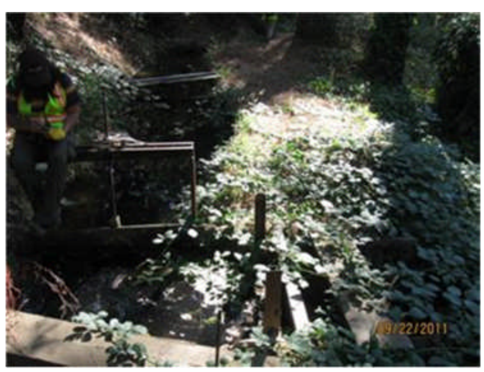


Photo 7
End Release at Spill #1 on San Diego

7.0 Operational Measures

Operational measures to reduce sources of non-consumptive use include monitoring system flows, throughout the system and implementing operation and maintenance practices. Sources of non-consumptive use controllable by operational practices include:

- Design/end releases
- Leakage
- Theft

7.1 SYSTEM MONITORING

Flow monitoring stations will be an important tool for operators. Currently, diversions to ditches are based on the historical knowledge and experience of the operators. The amount of water added to a given ditch depends on the season, weather conditions, customer requests, seepage rates, etc. The ditch operator must be sure to have enough water in the ditch that the last customer has adequate deliveries. Exactly matching the flow in the ditch to customer demands is impossible, so there is often excess flow diverted to be sure there is water at the end of the ditch and customers are receiving water.

The flow monitoring stations will provide critical information to operators to see real time flows in the ditch and to be able to make adjustments to match flow with deliveries and optimize system operation. The monitoring system will also provide information regarding seepage rates, theft, and warnings when there is an unexpected change in flows which could indicate a failure, or large amount of water entering the ditch system due to rainfall or snowmelt runoff. Early warning to large flow fluctuations will reduce the potential for damaging the ditch system and downslope property due to overflows are failures.

Over time, the flow data can be coupled with automated flow controls within the system. For instance, if flows exceed the system demand, an automated gate or valve could be activated to lower the flow at the head of the ditch, increasing system efficiency and decreasing operation and maintenance costs.

As the flow monitoring stations come online, the District operations and engineering staff will gain a better understanding of the raw water system.

7.2 LEAKAGE

Sources of leakage include burrows/breaches in the ditch embankments and releases from structures or pipelines. Except for large leaks resulting from a structure or embankment failure, most leaks are relatively small. Not only do leaks contribute to system inefficiency, they also have potential to cause other problems that include:

- Damage to the ditch embankments
- Potential to alter downstream habitat over time
- Cause damage to downstream property

District staff closely monitors the ditch system for leaks and repairs them quickly when discovered. Generally speaking, releases from leaks are considered a relatively minor source of non-consumptive use in the system, but staff should continue to monitor and aggressively repair leaks when discovered.

7.3 THEFT

Theft throughout the system is relatively minor and generally limited to remote areas where property owners steal water for agricultural purposes. These are generally through a garden hose, although there have been large scale diversion in the system. Operations staff is trained to identify illegal diversions during ditch monitoring activities, and once identified, take actions to eliminate the theft and will continue to do so.

8.0 Conclusions and Recommendations

Conclusions and recommendations from this study are included below.

8.1 CONCLUSIONS

Conclusions resulting from this study are included below:

- The District's raw water system is critical for water supply within the District boundary.
- Overall water supply in the arid west is a valuable resource and the District desires to be a good steward and manage its resources properly.
- In a 2003 study of the ditch system, the non-consumptive use components were estimated to be approximately 47-percent, which is similar in magnitude to other similar raw water systems utilizing ditches for conveyance. Since that time, the District has made improvements to the system and the current non-consumptive use component is likely to be less than that measured in 2003.
- Eighteen flow monitoring stations have been installed throughout the ditch system through a Proposition 50 grant. Ultimately, there will be a total of 24 permanent monitoring stations that will be equipped with radio transmitters to provide real time monitoring of flows in the ditches. The monitoring stations will be used to:
    - Provide early warning in the event of a problem in the system such as failure of a ditch, flume or pipeline caused by an act of vandalism or a natural event that interrupts flow
    - Locate illegal diversions of raw water
    - Allow operations staff to optimize system flow to prevent end releases
    - Provide insight with regards to areas of the system with higher than normal non-consumptive use components
- Temporary flow monitoring stations will likely be used to supplement flow data gathered by the permanent flow measuring stations.
- The District may consider adding additional permanent flow monitoring stations in the future to increase monitoring capability once the new system is operational.
- Seepage and end releases are considered the major non-consumptive use components in the system. Theft, evaporation, and adsorption are considered to be minor non-consumptive use components. Evaporation and adsorption are difficult to control.

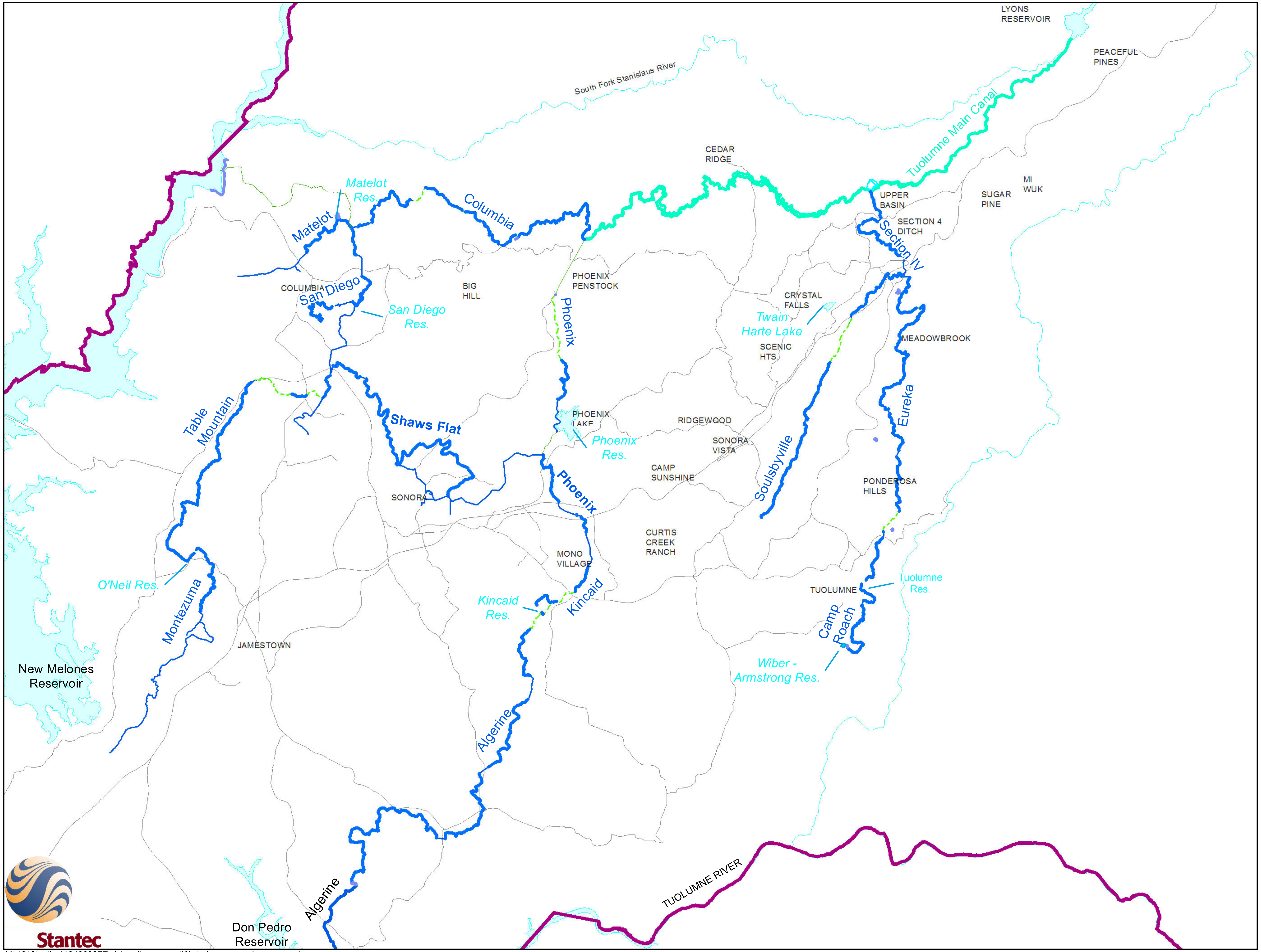
- Seepage can be reduced by guniting or piping the ditches; however, piping the system is considered to be cost prohibitive and has other environmental and cultural resources constraints.
- End releases can be reduced through implementation of capital improvement projects and use of flow monitoring data to optimize ditch operations.
- Operational and maintenance activities are already geared towards managing non-consumptive uses to the extent currently possible.
- The flow monitoring stations will increase operational efficiency and reliability. After completion of the flow monitoring program, it is likely that automation of some of the flow control structures will be desirable.
- Managing non-consumptive use will be a long-term program and is limited by operations and capital budgets.
- Non-consumptive use water leaving the conveyance system potentially enhances the ecosystem by creating wetlands/riparian areas, providing some level of groundwater recharge (the extent unknown), creating aesthetic benefit, and providing water for biota in the vicinity of the ditch. The level of enhancement varies through the system.
- During critical dry periods, utilizing water for ecosystem enhancement could negatively impact delivery of adequate supplies to municipal and industrial users in the District's service area.

8.2 RECOMMENDATIONS

Recommendations resulting from this study are included below:

- Managing non-consumptive use within the Ditch system should be an ongoing goal.
- The District should continue with the completion of the Proposition 50 flow monitoring project and supplement flow data, as needed, with temporary flow monitoring stations that can be installed in specific reaches to identify areas with abnormally seepage rates.
- Prioritization of areas of the system with abnormally high seepage rates should be used to determine which segments are lined first, taking into consideration non-consumptive use benefits as a factor in the prioritization process.

- An assessment of the potential impact to trees growing along the ditch corridors should be made and taken into consideration on future guniting projects. The potential impact of guniting has on trees growing along the ditches is discussed further in the Oak Tree section of the Case Study prepared as part of this project.
- Gunite lining has been, and will likely remain, the most cost effective means to reduce seepage in the system. The District should assess the effectiveness of the guniting by re-measuring seepage after completion of guniting projects. Potential modifications to historical guniting practices may include the addition of a flexible plastic liner under the gunite to provide additional sealing but this should be assessed through a small scale pilot study.
- Implementation of CIP projects to reduce end releases should be budgeted for and planned. Four specific projects include:
    - Matelot Reservoir pipeline to the Columbia Water Treatment Plant
    - Addition of an equalizing reservoir at the end of the Montezuma Ditch, just prior to the piped segment
    - Utilization of the Wiber-Armstrong Ponds for flow equalization at the end of the Camp Roaches Ditch
    - Utilization of a level sensor in the Blue Gulch Reservoir at the end of the Algerine Ditch
- Ongoing operation and maintenance activities currently address leaks and theft and should continue to be practiced.
- Once the flow monitoring stations are all installed and equipped, operations and engineering staff will gain valuable insight with regards to ditch system operation. Utilization of this information to identify operational modifications to improve system efficiency should be a priority.
- Board policy will determine the allocation of the District’s water resources between ecosystem enhancement and water supply for municipal and industrial use. Targeting high value ecosystems along the ditch system may be a means by which ecosystem enhancement and water supply goals can be met.



Legend

- Canal Centerline
- Main Tuolumne Canal
- Piped Section
- Random Section
- Penstock
- Reservoir
- Major Roads
- Rivers
- Lakes
- TUD Service Area Boundary

N

Notes
1. Sources: Basemap data - Tuolumne County 2011; Canal infrastructure - Tuolumne Utilites District 2011; TUD Service Area - CalFire/Stantec 2012
2. Roads not labeled for clarity

0 3
Miles

TUOLUMNE UTILITIES DISTRICT DITCH SYSTEM SUSTAINABILITY PROJECT - OPERATION AND MANAGEMENT STRATEGIES REPORT

FIGURE 1

SYSTEM OVERVIEW

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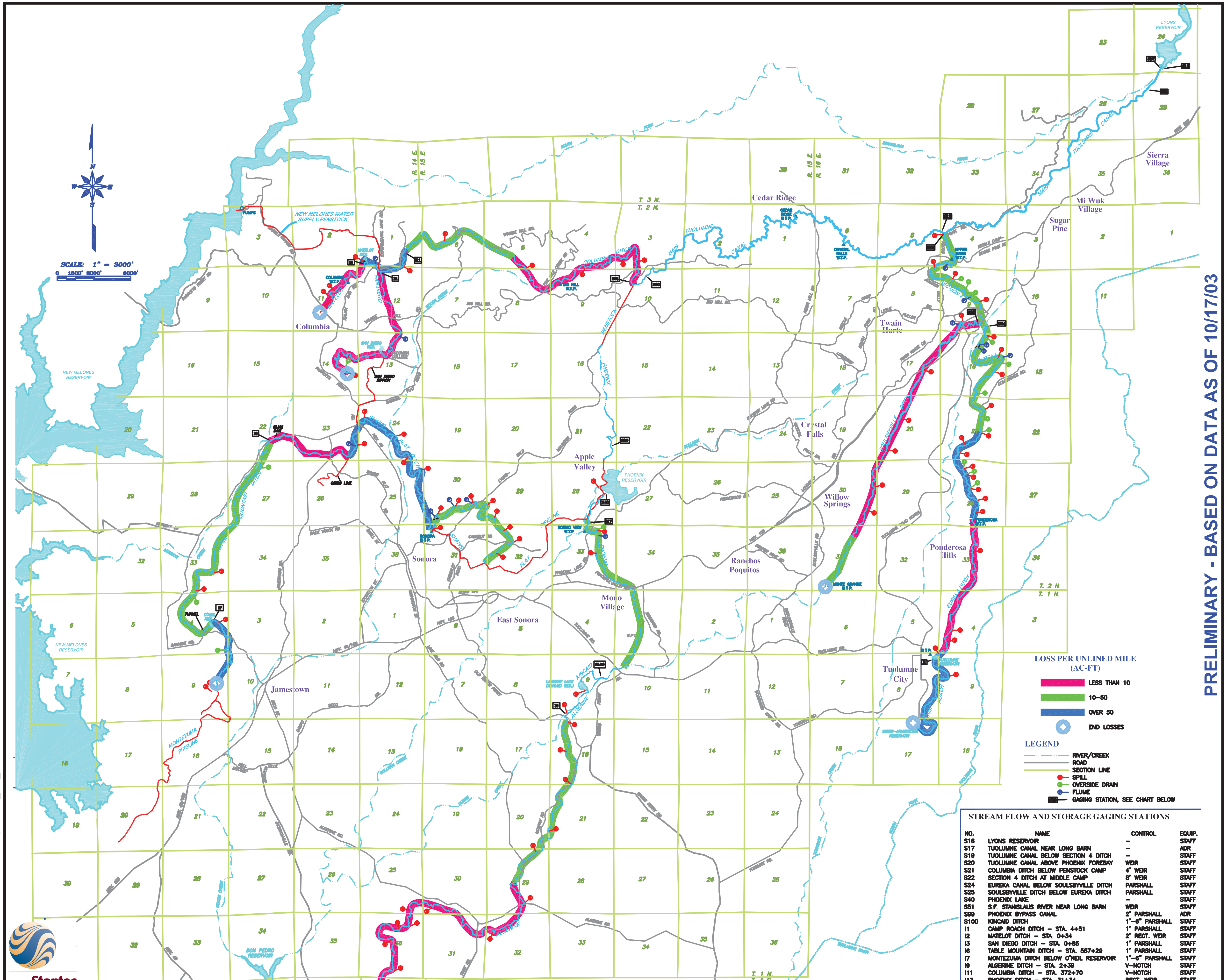

STREAM FLOW AND STORAGE GAGING STATIONS

NO.	NAME	CONTROL	EQUIP.
S16	LYONS RESERVOIR	–	STAFF
S17	TUOLUMNE CANAL NEAR LONG BARN	–	ADR
S19	TUOLUMNE CANAL BELOW SECTION 4 DITCH	–	STAFF
S20	TUOLUMNE CANAL ABOVE PHOENIX FOREBAY	WEIR	STAFF
S21	COLUMBIA DITCH BELOW PENSTOCK CAMP	4' WEIR	STAFF
S22	SECTION 4 DITCH AT MIDDLE CAMP	8' WEIR	STAFF
S24	EUREKA CANAL BELOW SOULSBYVILLE DITCH	PARSHALL	STAFF
S25	SOULSBYVILLE DITCH BELOW EUREKA DITCH	PARSHALL	STAFF
S40	PHOENIX LAKE	–	STAFF
S51	S.F. STANISLAUS RIVER NEAR LONG BARN	WEIR	STAFF
S99	PHOENIX BYPASS CANAL	2' PARSHALL	ADR
S100	KINCAID DITCH	1'–6" PARSHALL	STAFF
I1	CAMP ROACH DITCH – STA. 4+51	1' PARSHALL	STAFF
I2	MATELOT DITCH – STA. 0+34	2' RECT. WEIR	STAFF
I3	SAN DIEGO DITCH – STA. 0+85	1' PARSHALL	STAFF
I6	TABLE MOUNTAIN DITCH – STA. 587+29	1' PARSHALL	STAFF
I7	MONTEZUMA DITCH BELOW O'NEIL RESERVOIR	1'–6" PARSHALL	STAFF
I9	ALGERINE DITCH – STA. 2+39	V–NOTCH	STAFF
I11	COLUMBIA DITCH – STA. 372+70	V–NOTCH	STAFF
I17	PHOENIX DITCH – STA. 31+34	RECT. WEIR	STAFF

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FIGURE 2

2003 ESTIMATED LOSSES

Adopted from:
Tuolumne Utilities District Ditch Optimization Plan - Water Balance Study, EIP Associates, 2003

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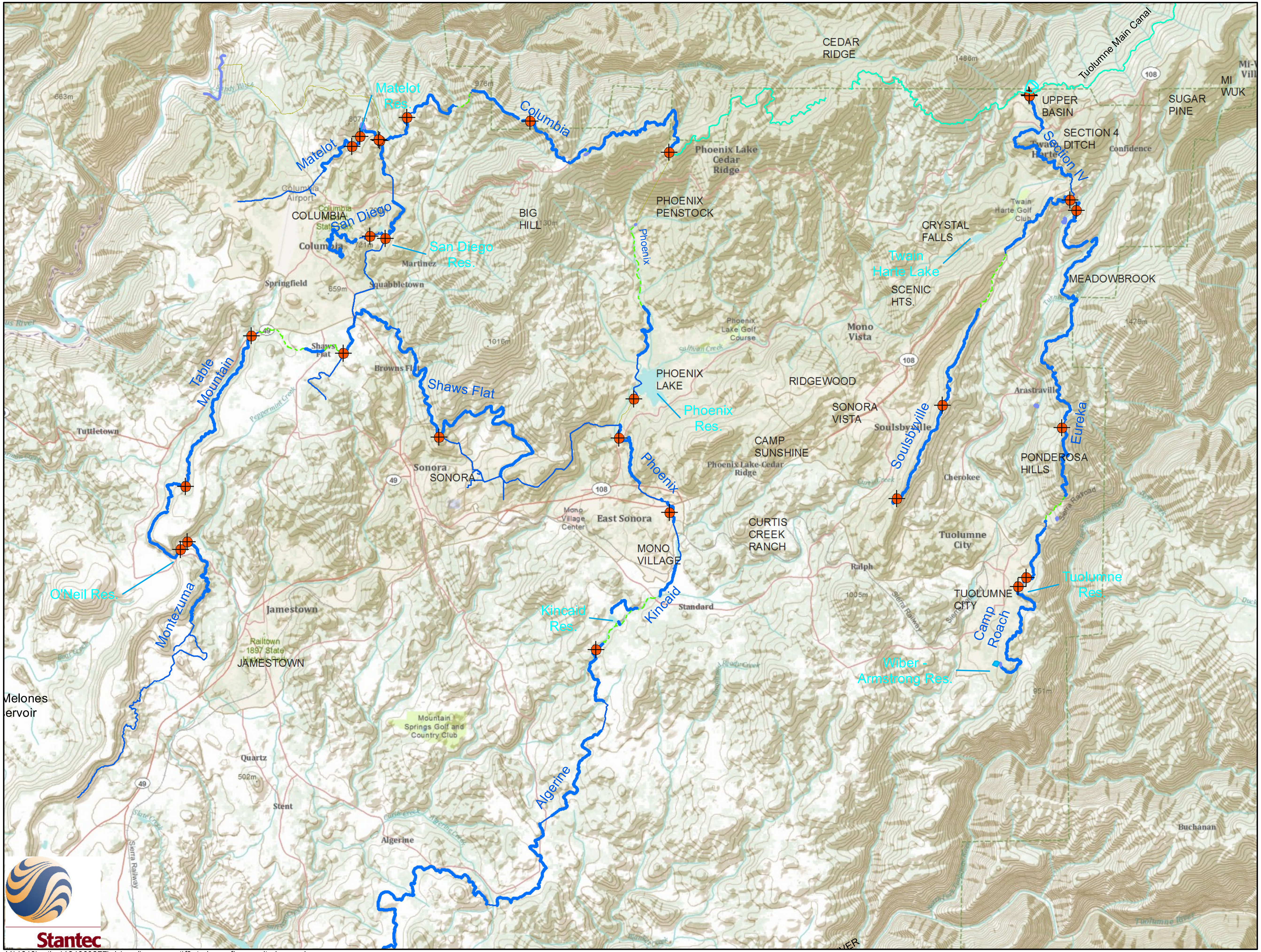

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Legend

- Gaging Station
- Canal Centerline
- Main Tuolumne Canal
- Piped Section
- Random Section
- Penstock
- Reservoir

N

Notes
1. Sources: Basemap data - Earth Systems Research Institute Inc. 2011; Canal infrastructure - Tuolumne Utilites District 2011; Stantec 2012
2. Roads not labeled for clarity

0 2
Miles

TUOLUMNE UTILITIES DISTRICT DITCH SYSTEM SUSTAINABILITY PROJECT - OPERATION AND MANAGEMENT STRATEGIES REPORT

FIGURE 3

FLOW MONITORING STATIONS

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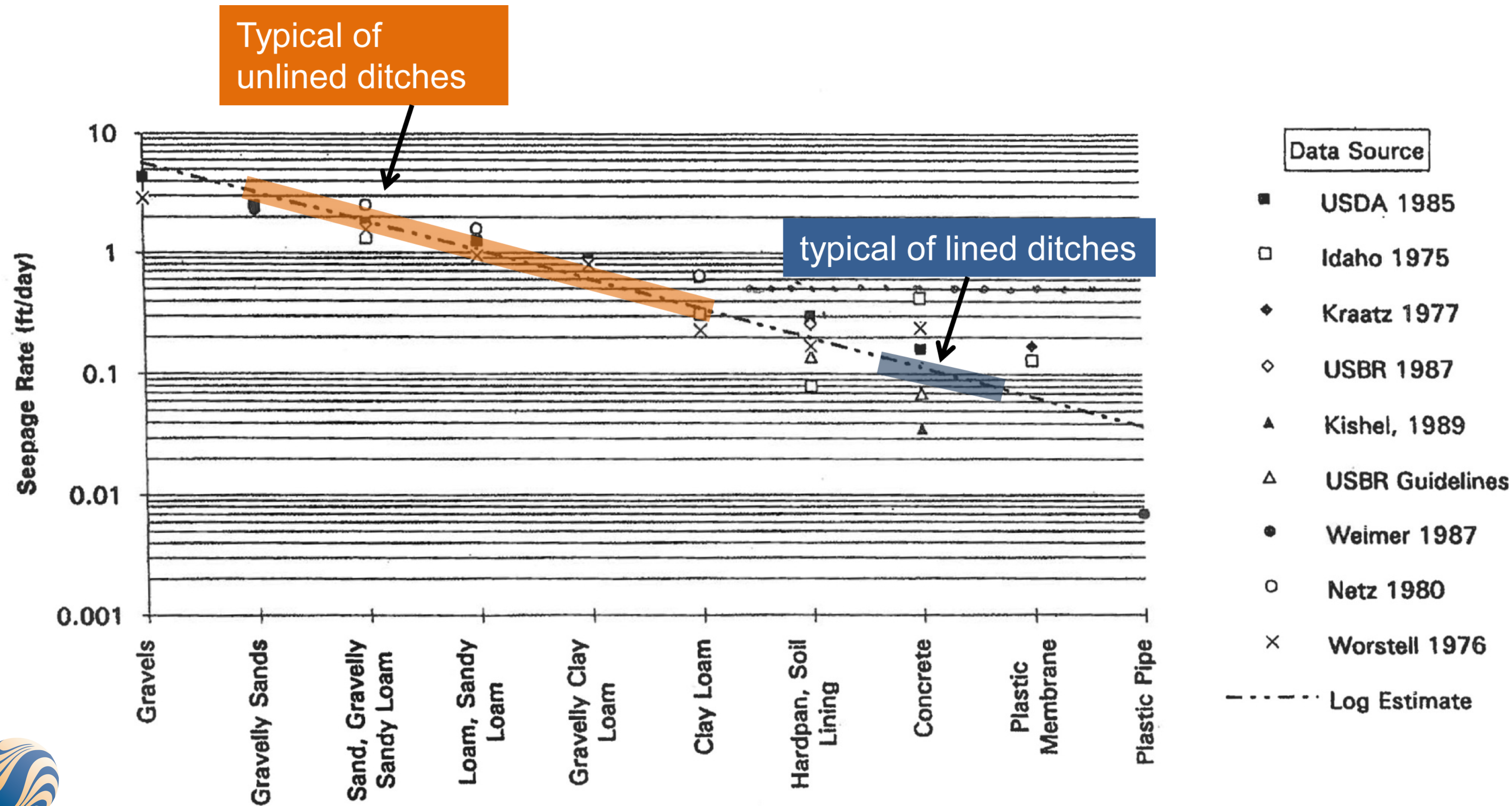

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Stantec

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FIGURE 4

TYPICAL SEEPAGE RATES