Transient Pressure Monitoring Program – Nacimiento Water Project

Will Worthington, P. E., M. ASCE [1]; John R. Hollenbeck, P. E., M. ASCE [2]

[1] President, Pipetech International, PO Box 6054, Carefree, AZ 85377
will@pipepressure.com

[2] Nacimiento Project Manager, San Luis Obispo County Flood Control and Water Conservation District, County Government Center-Room 207, San Luis Obispo, CA 93408, jhollenbeck@co.slo.ca.us

Abstract

The Nacimiento Water Project under construction in San Luis Obispo County, California, will deliver 15,750 acre-feet of raw water annually from Lake Nacimiento through 45 miles of pipeline to its service area. The Project includes three pumping stations, three storage tanks, 45 miles of pipeline ranging from 36- to 12- inches in diameter, and a SCADA system. The hydraulic aspects of the system dictated careful attention to hydraulic design, with due consideration of normal and transient pressures. As a follow-up to the hydraulic design, the project will include a very rigorous transient monitoring program, possibly the most intensive on any pipeline in the USA to-date. This transient monitoring program scheduled for installation in March 2010 includes nine TP-1 transient monitoring systems installed at locations most prone to severe hydraulic transients. These systems provide detailed information regarding transient pressures and are integrated into the SCADA system to provide real-time alerts if threshold pressures are exceeded. This paper describes the Nacimiento Water Project, the hydraulic design considerations, the network of transient monitoring systems that is installed, and the results of transient pressure monitoring collected to-date.

Project Description

The Nacimiento Water Project (Project), illustrated in Figure 1, will convey up to 15,750 acre-feet annually from Lake Nacimiento in San Luis Obispo County, California, through 45 miles of pipeline ranging from 36- to 12-inches in diameter. The Project includes three pump stations, three water storage tanks, and a supervisory and control and data acquisition (SCADA) system. Four turnouts are included to provide delivery to the Project participants: the City of Paso Robles, Templeton Community Services District, Atascadero Mutual Water Company, and the City of San Luis Obispo. Design of the $176-million Project began in 2004 and construction is currently in progress, with operational testing scheduled for completion in December 2010.

The Project's hydraulic design played an important role in the engineering effort. It established key Project features that significantly affected the Project construction and operating costs. The design gave careful attention to phased water deliveries, hydraulic efficiency, optimum pipe diameters, pump station characteristics, transient pressure control measures and potential energy recovery.

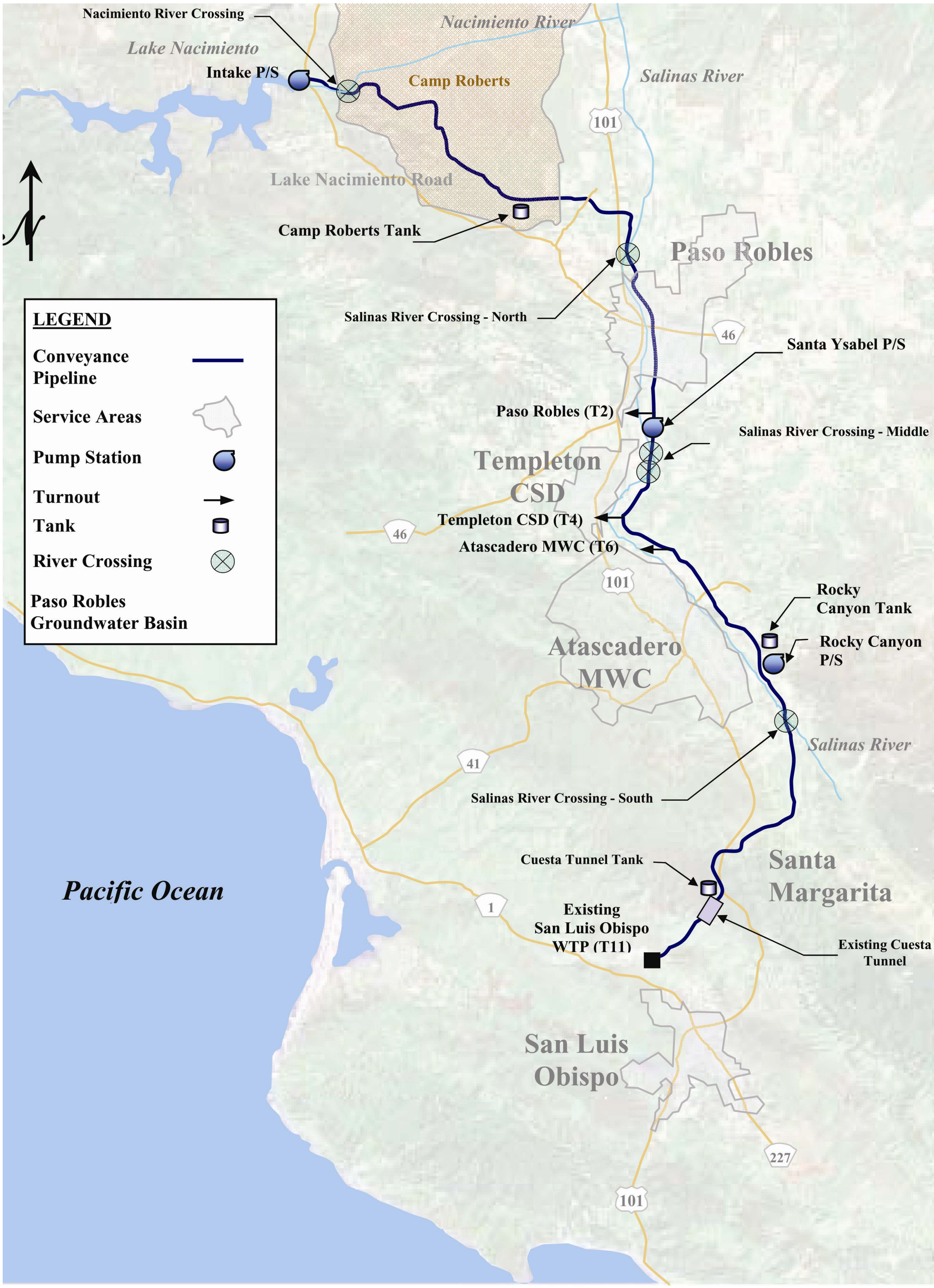

Figure 1. Nacimiento Water Project Unit Map

The Project will operate as a pumped system under normal operation, and as a result the most significant hydraulic event will likely be generated by emergency operation, sudden power loss at one or more of the pump stations, or malfunction at one of the turnouts. Extensive surge modeling of the pipeline allowed the design of surge control facilities conforming to two criteria:

- Minimum pressure due to downsurge would always be above atmospheric pressure, and
- Minimum pressure during upsurge would not exceed initial hydraulic grade line by more than 100 feet.

The hydraulic modeling guided the selection of these facilities to control surge due to pump station power failure:

- Air chambers on the discharge of the Intake, Santa Ysabel, and Rocky Canyon Pump Stations
- Slow closing air/vacuum valves at high points along pipeline
- Surge relief valves on the suction side of Santa Ysabel Pump Station

Characteristics and Capabilities - TP-1 Transient Pressure Monitoring System

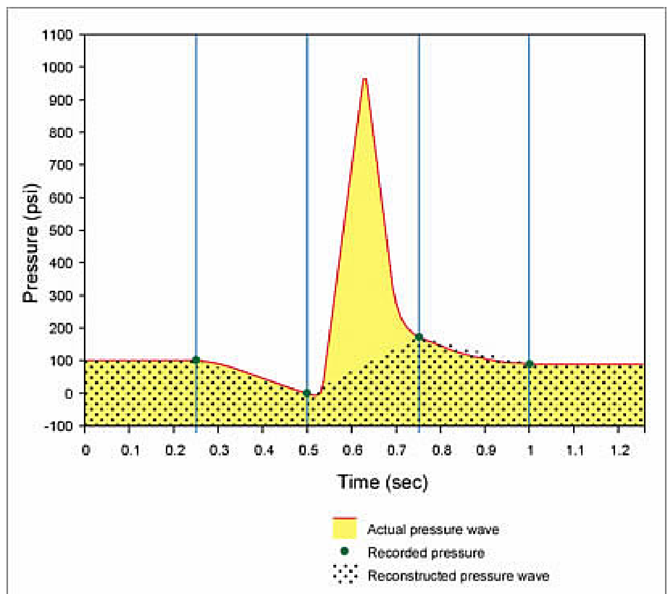

Figure 2 - Digital data collection with insufficient sample rate

The Project engineers recognized the importance of measuring transient pressures at critical points in the Project; and included standard digital data loggers which have become widely used within the water and petroleum pipeline industry. On this Project, however, there is a need to monitor for indefinite periods with the capability to detect and measure an unexpected transient that may last a fraction of a second. Not only are these events difficult to detect, they may be the most damaging of all and may go unnoticed for long periods of time. One of the most important aspects of digital sampling of pressure data is selection of an appropriate data sampling rate. An intensive sampling program might sample once per second generating 86,400 data points per day at each test station. Still this would be insufficient to accurately record an event lasting a fraction of a second. As is noted in Figure 2, an insufficient sample rate will lead to inaccurate and misleading portrayal of pressure.

Within the past several years, a system has been devised that overcomes several of the limitations of previous digital systems. It is capable of monitoring over extended period of time in a “snoozing” mode, recording background pressure at a user-set interval between once per second and once per day. Although the system appears to be snoozing, in reality it is very busy. It continuously samples the pressure 1000 times per second and computes a running average. Effectively the system algorithm has a built-in alarm clock that goes off when a pressure is detected that differs significantly from the average – in other words when a transient is detected. When this occurs, the system "wakes up" and records all data at another user-set rate up to 100 Hz. This continues until the transient has passed, at which time the system goes back to the "snoozing" mode. The scheme is shown graphically in Figure 3.

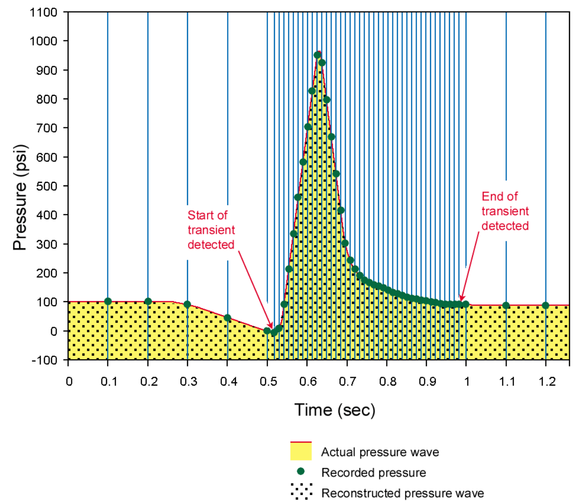

Figure 3 – TP-1 Data Recording Scheme

An additional feature of the TP-1 system is its inclusion of precision timing of pressure data using the GPS satellite constellation, thus providing the time that each data point was recorded in addition to the pressure data itself taken at 100 Hz. This capability provides an additional dimension to troubleshooting of pipeline problems and the analysis of transient data, allowing the localization of the source of a transient event where multiple TP-1 monitors are used and the instant of detection of a transient event is available to millisecond accuracy.

The TP-1 system allows users to set parameters that govern data analysis and recording, including the steady-flow background record rate, the transient event record rate, and criteria for transitioning from background to transient record modes. The system incorporates a transducer with a frequency response range to one KHz to capitalize on the high-speed data recording capability of the TP-1. It is connected hydraulically to the pipeline through standard ¼" NPT fittings, and is connected electrically to the TP-1 controller through a shielded cable. Cable lengths up to 300 feet have been successfully used. Pressure data recorded by the TP-1 system is stored on internal two-GB flash drive memory, providing storage for months of data storage under normal conditions. Data is uploaded from the TP-1 via wireless, LAN, or Ethernet connections for analysis by the user. Data is placed in a standard Microsoft Data Base for ease of analysis, and the analysis process is further facilitated by software that is part of the TP-1 system. The top graph in Figure 5 depicts a typical data upload of 18 days of data, with steady state shown in blue and transient events in red. Normal operating pressure of 130 psi is observed, however a maximum pressure of 270 was reached during one transient event. The lower graph in Figure 5 shows five seconds of data, including the details of that one-second event that produced that maximum pressure.

Figure 4 – TP-1 Transient Pressure Monitoring System

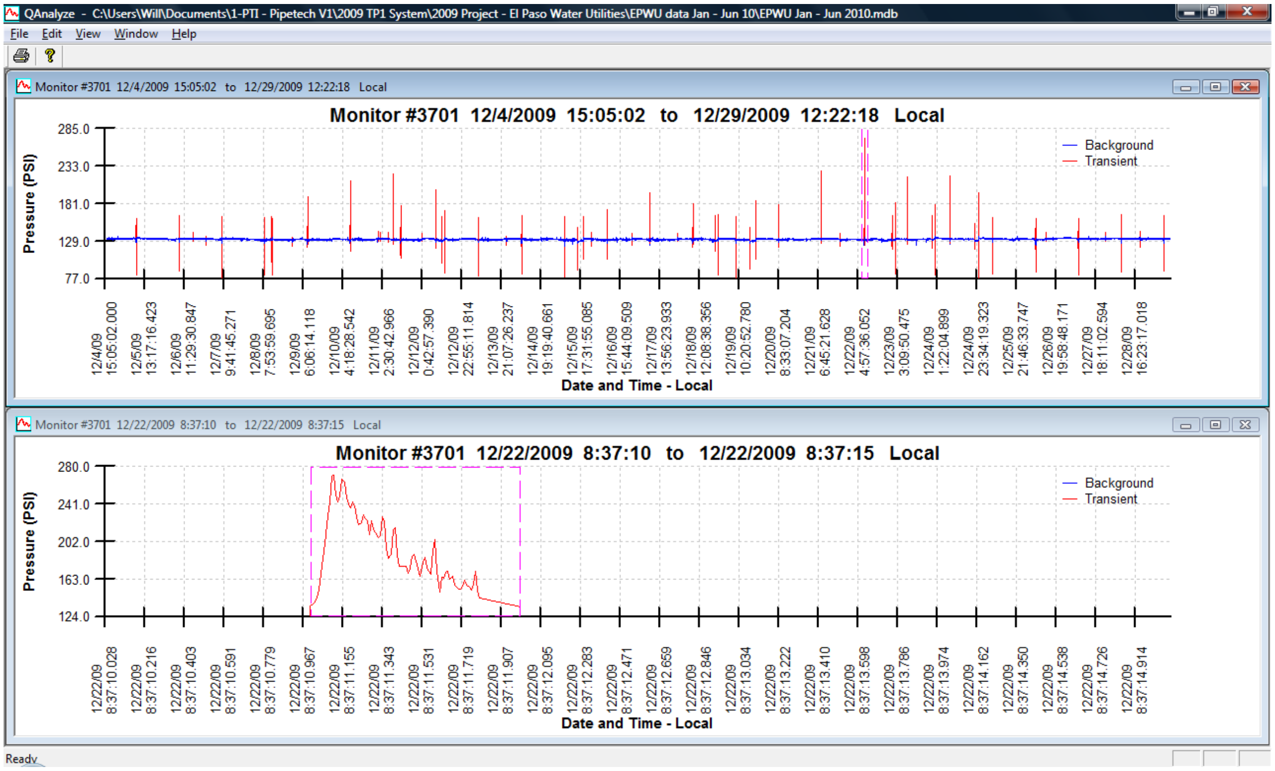

Figure 5 – TP-1 Pressure Data – Showing 18 days (Top) and 5 Seconds (Bottom)

Installation of Transient Pressure Monitoring System on the Nacimiento Water Project

Discussions among the Project manager and design engineers determined that the optimum locations of the TP-1 systems would be pumping station suction and discharge lines, high-volume turnouts, and points of highest elevation (and thus lowest pressure head). This resulted in a plan to install nine transient pressure monitoring devices on the Project, making if perhaps the most intensively monitored pipeline today, in terms of transient pressure recording. The locations selected:

- Intake pump station discharge header
- High point upstream of the Camp Roberts Tank
- Paso Robles, Atascadero, and San Luis Opbispo turnouts
- Suction and discharge headers at Santa Ysabel and Rocky Canyon Pump Stations

Figure 6 – Rodky Canyon Pump Station
Installation

Figure 7 - Rocky Canyon Pump

Figure 8 – Camp Roberts Tank Construction
Station Pumps

Figure 9 – Santa Ysabel Pump

The TP-1 requires 700 milliamps of 12 volt DC power, which is normally provided via 120 volt AC power through a converter. At the Camp Roberts Tank location, AC power is not available, so the installation there will include a solar panel and battery storage.

The TP-1's would be modified by the manufacturer to provide Ethernet communication with the Project SCADA system, providing the capability to access the TP-1 system to modify operational parameters and retrieve data. As an additional enhancement, the GPS time synchronization capability of the TP-1's would be used to synchronize time at the power monitor located in switch gear at each of the three pump stations.

The installation of the TP-1 systems will be accomplished through a modification to the general construction contract for appurtenant facilities on the Project. The general contractor in turn has entered into sub-contracts with the TP-1 supplier, the electrical sub-contractor, and the system coordinator to furnish and install the transient monitoring devices.

Status of Project Construction and Transient Pressure Monitoring

Construction of the Project began in February 2008, and is projected to be operationally tested and delivering water by December 2010.

Award of the contract modification for the TP-1 contract was accomplished in January 2010, several months later than originally anticipated. The TP-1 systems are scheduled to be installed in March 2010 and will allow recording of operational testing of the pipeline. We anticipate that the data will validate the hydraulic models and confirm the proper functioning of the surge control features of the Project.

The TP-1 contract includes data reviews and analysis at 30 days and again at 60 days of pressure monitoring. Results of this testing and conclusions will be included to the extent feasible in the final draft of this paper, as well as the paper presentation.

References

Hollenbeck, John R., Paul Kneitz, Steve Foellmi, and Andrew Romer (2009); "Nacimiento Water Project – Design and Hydraulics;" ASCE Pipeline Conference, San Diego

Worthington, Will (2005), "Monitoring for Transient Pressures in Pipelines," ASCE Pipelines Conference, Houston

San Luis Obispo County, CA;
http://www.slocounty.ca.gov/PW/NacWP/Construction_Phase.htm