Applying a Modified Triad Approach to Investigate Wastewater lines

R. Pawlowicz, L. Urizar
Bechtel National, Inc.
1230 Columbia St., Suite 400, San Diego, CA 92101

S. Blanchard
Brown and Caldwell
9665 Chesapeake Drive, Suite 201, San Diego, CA 92123

K. Jacobsen
Naval Facilities Engineering Command, Southwest
1220 Pacific Highway, San Diego, CA 92132

J. Scholfield
EarthTech
841 Bishop St., Suite 500, Honolulu, HI 96813

ABSTRACT

Approximately 20 miles of wastewater lines are below grade at an active military Base. This piping network feeds or fed domestic or industrial wastewater treatment plants on the Base. Past wastewater line investigations indicated potential contaminant releases to soil and groundwater. Further environmental assessment was recommended to characterize the lines because of possible releases. A Remedial Investigation (RI) using random sampling or use of sampling points spaced at predetermined distances along the entire length of the wastewater lines, however, would be inefficient and cost prohibitive. To accomplish RI goals efficiently and within budget, a modified Triad approach was used to design a defensible sampling and analysis plan and perform the investigation. The RI task was successfully executed and resulted in a reduced fieldwork schedule, and sampling and analytical costs.

Results indicated that no major releases occurred at the biased sampling points. It was reasonably extrapolated that since releases did not occur at the most likely locations, then the entire length of a particular wastewater line segment was unlikely to have contaminated soil or groundwater and was recommended for no further action. A determination of no further action was recommended for the majority of the waste lines after completing the investigation. The modified Triad approach was successful and a similar approach could be applied to investigate wastewater lines on other United States Department of Defense or Department of Energy facilities.

INTRODUCTION

There is an extensive network of domestic (approximately 18 miles in length) and industrial (approximately 2 miles in length wastewater lines) underlying a major portion of the active military Base. The lines consist primarily of piping, plus drainage pipes/culverts, and open ditches. The wastewater lines were laid at a depth of approximately 3 to 17 feet below ground surface. At present, most of the domestic wastewater line is active and permitted, whereas the industrial line is no longer in use but is still in place.

The domestic lines were installed beginning in 1942 at the start of Base operations. These wastewater lines are constructed of various materials (e.g., vitrified clay, carbon steel or concrete) and are of varying diameters (4 to 21 inches). Originally, the domestic lines fed an old wastewater treatment plant (demolished). In 1978, the lines were rerouted to the new wastewater plant that presently treats domestic wastewater at the Base.

The domestic lines received both domestic and industrial wastewater from a variety of sources on Base prior to opening of the industrial wastewater treatment plant. In general, discharge of industrial wastewater into the domestic lines ceased when the industrial wastewater treatment plant opened in 1978.

The industrial lines were installed beginning in 1972, were constructed of 8-inch diameter polyvinyl chloride (PVC), and were tied into the industrial wastewater treatment plant in 1978. On-Base treatment of industrial wastewater was performed until plant shutdown in 1990. Since that time, industrial wastewater is being collected for transport and treatment off-Base. In the mid-1990s, connections, drains and manholes were sealed and plugged with concrete to prevent discharges to the lines. The industrial lines are now inactive and nonfunctional.

Several studies (inspection and environmental sampling) of the wastewater lines have been completed since the industrial wastewater treatment plant stopped operations. A Closed Circuit Television (CCTV) Investigation was conducted in 1994 to assess the integrity of wastewater lines on the Base. Approximately 34 percent of the domestic and 86 percent of the length of the industrial wastewater lines were investigated in this study. The CCTV survey revealed wastewater line breaks/defects (e.g., cracks, broken pipe segments, and offset joints) where releases may have occurred from either line.

Past environmental studies of the domestic and industrial wastewater lines identified the presence of possible contaminants in surface soil, the unsaturated (vadose) zone, and groundwater at the Base. The source of these contaminants may have been the domestic and previously active industrial wastewater lines. A modified Triad approach was used for the RI to characterize environmental media that may have been impacted by leakage of contaminants from the wastewater lines.

BASE HISTORY

The Base was established in 1942 to serve as a staging area for supplies and equipment for forces deployed in the Pacific region during World War II. In 1943, the Base began providing logistical support to commands throughout the western United States and Pacific region. Major industrial operations were conducted at the Base until the early 1960s, when these functions were relocated to a different area of the Base.

SURFACE FEATURES

The domestic and industrial wastewater lines are mostly located beneath streets and other paved areas. The topography of this area of the Base varies with slopes of 1 percent or less to greater than 5 percent (Figure 1).

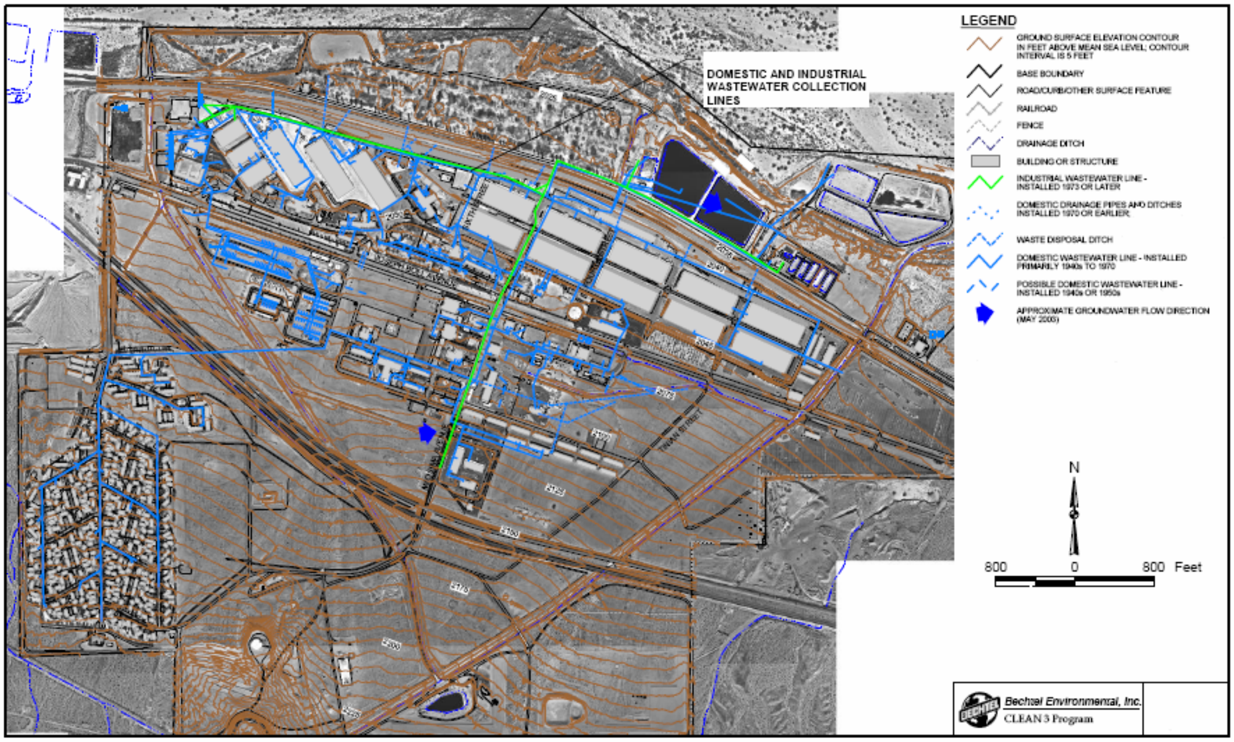

Fig. 1. Topographic map showing location of domestic and industrial wastewater lines

The geology encompassing and underlying the domestic and industrial wastewater lines consists of alluvial fan and fluvial sediments, and varies somewhat from the northern to southern areas of the Base. The northern area of the wastewater collection lines are predominantly underlain by loose- to very-dense, silty sands to poorly graded sands with some gravel, with occasional well-graded sand, gravel, and sandy clay layers. Groundwater is encountered in the northern area from approximately 19 to 39 feet bgs. The lithology of the saturated zone to the depth drilled consists predominantly of fine- to medium-grained, poorly graded sands with some well-graded sands. The groundwater flow direction in the northern area varies but is generally to the east toward a known fault zone that cuts across the Base.

The southern area of the wastewater collection lines is predominantly underlain by medium-dense to very-dense, well-graded sands and silty sands with some gravel, with some interbedded gravel, poorly graded sand and clayey sand layers. Clayey sands, clays, and silts are more prominent below approximately 85 feet bgs, with some layers being 10 to 20 feet or more in thickness. Groundwater is encountered in the southern area from approximately 84 to 115 feet bgs. The lithology of the saturated zone to the depth drilled consists predominantly of clayey sands to clays and silty sands. The groundwater flow direction in the southern area of the wastewater collection lines is generally to the northeast.

HYDROGEOLOGY

Groundwater elevations at each individual wastewater line vary with their location at the Base. Two aquifers are present. In general, groundwater conditions in the northern portion of the Base can be characterized as an unconfined, relatively shallow aquifer underlying a floodplain and river. The southern area of the Base is characterized by a regional aquifer.

The shallow aquifer consists of recent and younger alluvium. The hydraulic conductivity of the shallow aquifer averages 150 feet/day. The regional aquifer is more than 1,000 feet thick in some areas and consists of younger and older alluvial fan deposits and older alluvium. This aquifer system is generally less permeable than the shallow aquifer. The hydraulic conductivity of the regional aquifer averages 1.5 feet/day.

Recharge to the groundwater systems occurs primarily from infiltration of river floodways, irrigation-return flow, and groundwater underflow from basins upstream. Precipitation in this area is low and potential evaporation is high, little, if any, recharge occurs as a result of direct infiltration of precipitation.

The observed groundwater flow patterns indicate a significant influence from the known fault zone that crosses the Base. East of the fault zone, the groundwater flow was generally to the southeast with a fairly consistent hydraulic gradient of approximately 0.0035 foot per foot (ft/ft). West of the fault zone, groundwater flow was generally east-northeast with a hydraulic gradient ranging from 0.0026 to 0.021 ft/ft (Figure 2).

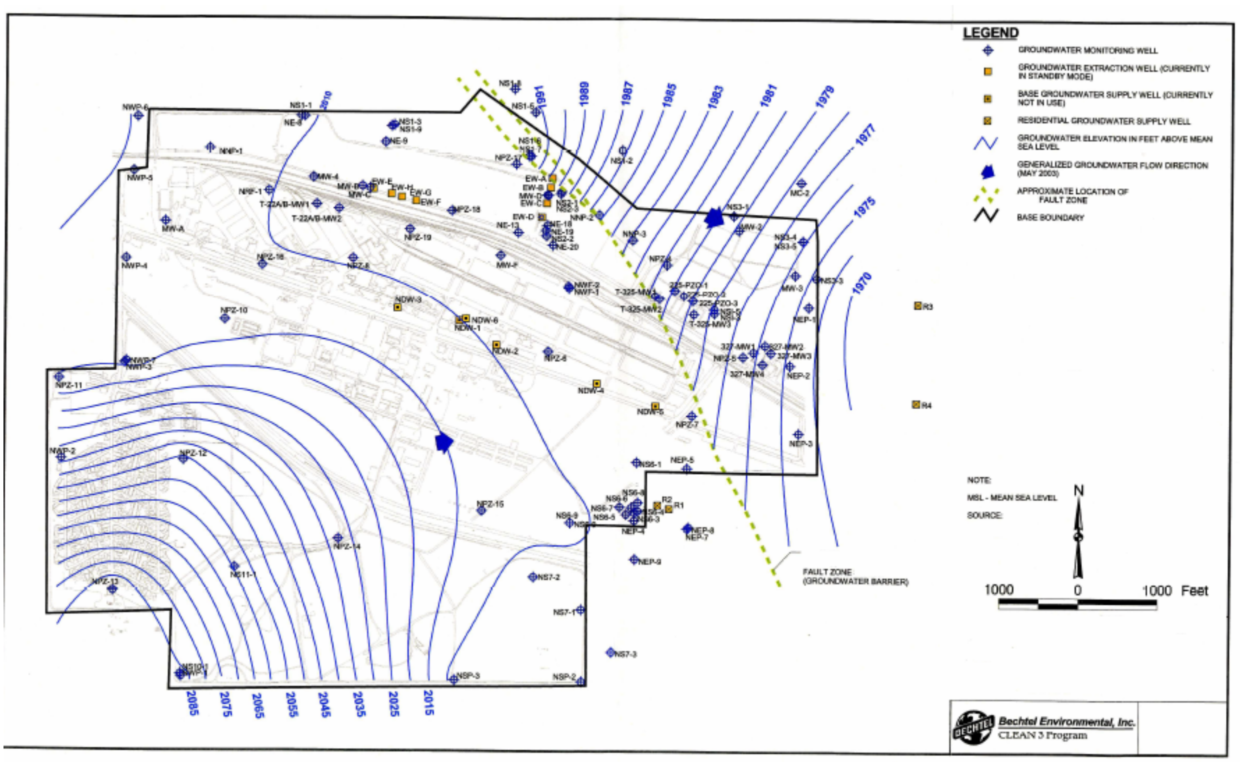

Fig. 2 Potentiometric Surface Contour Map

MODIFIED TRIAD APPROACH RATIONALE

A Navy team that included Bechtel National, Inc. used a systematic project planning and dynamic work strategy (modified TRIAD approach) to characterize the wastewater lines at the Base. In addition, state and federal agencies were part of the proactive team that designed the defensible sampling and analysis plan for the wastewater lines.

The rationale used is summarized in the context of the Data Quality Objectives (DQO) development process, as described in U.S. EPA guidance (U.S. EPA 2000). The DQO process provided the basis for developing the investigative approach used for the wastewater lines at the Base.

The DQO process formed the framework for systematic planning to capitalize on known history of Base activities and historical data to optimize data collection activities. The process helped formulate the criteria that data collection must satisfy, which resulted in a scientifically sound and resource (cost)-effective collection of data. Table I presents the DQOs and dynamic sampling plan for characterization of the wastewater lines on the Base.

This sampling strategy was developed to define data needs and the most appropriate number of samples to collect, establish the quality of data to support decisions, and balance available resources (cost) with risk. In addition, the modified Triad approach to investigation of the wastewater lines used another critical component that reduced the complexity of characterizing the wastewater lines; thoroughly evaluating wastewater line segment usage and location.

The complete wastewater line system was evaluated based on:

- the routes of individual lines and their proximity to other line(s),
- facility(ies) that had the potential to discharge industrial waste to an individual line,
- historical information concerning the lines and discharged waste,
- an evaluation of historical environmental data for line segments, and
- the number and distribution of sampling locations near or along line segments.

Table I. Summary of Data Quality Objectives for Domestic and Industrial Wastewater Lines

Step	Process	Response
1	State the problem.	The following are specific problems associated with the wastewater lines: • Previous data indicate that wastewater line breaks/defects are located down-flow of Base facilities, which reportedly discharged industrial wastewater. If leaks occurred from the wastewater lines down flow of any of these facilities, chemicals present in the wastewater might have contaminated underlying soil or groundwater. • Limited environmental data were collected at down-flow locations. Therefore, further investigation was needed to evaluate the potential that leaks may have contaminated soil or groundwater. • Previous soil gas sampling indicated the presence of soil impacted by several VOCs. Further investigation was needed to evaluate whether leakage from the wastewater lines may have contributed to the VOCs. • TCE in groundwater is present below the wastewater line. Facilities that were reported to have discharged industrial wastewater along this segment may have contributed TCE contamination to the vadose zone and groundwater. Further investigation was needed in that area. • The COPCs consist of contaminants reported in samples collected from soil, soil gas, and groundwater near individual wastewater lines or portions of lines. These COPCs included SVOCs, PCBs/pesticides, and metals in soil and VOCs in soil gas and groundwater. Further investigation was needed to evaluate whether leakage from the wastewater lines may have contributed to COPCs.

Table I. Summary of Data Quality Objectives for Domestic and Industrial Wastewater Lines (continued)

Step	Process	Response
2	Identify decisions that address the problem.	The following decisions were considered to resolve the problem statements presented in Step 1 so that the most correct outcome could be recommended for the wastewater lines: • Have contaminants in industrial waste liquids, discharged in the past to the wastewater collection lines, leaked from damaged lines down-flow of the generating facilities, and impacted soil or groundwater? • Have the nature and extent of the contaminants reported in soil or groundwater from releases from potentially damaged wastewater collection lines been defined? • If contaminants are present in soil at locations sampled during this study or previous investigations, have they or will they likely impact groundwater? • If contaminants are present at locations sampled during this study or previous investigations, do the concentrations pose an unacceptable risk to human health or the environment? • If contaminants are present at locations sampled during this study or previous investigations, and the concentrations pose an unacceptable risk to human health or the environment, has sufficient data been collected to provide information to develop remedial action alternatives?
3	Identify inputs that affect the decision.	Inputs necessary to make the decisions identified in Step 2 include the following: • Historical results from chemical analyses of soil, soil gas, and groundwater samples. • Spatial distribution relative to the wastewater lines of all previous and proposed sampling locations utilized for this study and other investigations. • Locations of damaged pipe sections identified in the CCTV investigation and damaged sections proposed for repair. • Locations of facilities that had discharged or potentially discharged industrial waste to the domestic and/or industrial wastewater lines, and the type of wastes discharged. • The extent of each domestic and/or industrial wastewater line segment as defined in the characterization plan. • Information on wastewater line repairs. • Identification of a known groundwater plume source area relative to the wastewater lines. • Results of the baseline human-health risk assessment using all data collected for the characterization study. • The acceptable human-health risk range as stated in the NCP.
4	What are the study boundaries?	The physical boundaries of this site consist of the extent along the domestic and industrial wastewater lines at the Base, as shown on Figure 2. Borings were advanced adjacent to the lines. This distance varied depending on site conditions, but was generally a minimum of 3 feet laterally from the lines. The vertical boundary of the investigation extends from ground surface to the water table, which varies from approximately 25 feet bgs to over 100 feet bgs.

Table I. Summary of Data Quality Objectives for Domestic and Industrial Wastewater Lines (continued)

Step	Process	Response
5	Identify decision rules.	Decision rules are required to state explicitly the types of inputs and logical basis for choosing among alternative actions during the study. The specific decision rules to determine an action were as follows: • If facilities were reported to have discharged industrial wastes to the wastewater lines, and the nature and extent or potential presence of COPCs in soil, soil gas, or groundwater have not been defined down-flow of these facilities, then conduct Tier 1 sampling to assess the nature and extent or potential presence of COPCs (Figure 2). • If the results of a vadose zone (soil or soil gas) sample from a Tier 1 boring at a specific location indicate that PRGs, action levels, or background concentrations of the COPCs are not exceeded, then no further investigation will be recommended for the vadose zone at that location. • If the results of a vadose zone (soil or soil gas) sample from a Tier 1 boring at a specific location indicate that PRGs, action levels, or background concentrations of the COPCs are exceeded, then the results will be evaluated for possible Tier 2 vadose zone sampling at that location. • If Tier 2 vadose zone sampling is considered necessary at a specific Tier 1 boring location, then the nature and extent of COPCs in soil and/or soil gas will be assessed at that location. • If groundwater is encountered during Tier 2 vadose zone sampling, then a groundwater sample will be collected. • If the results of the groundwater sample collected at a specific Tier 1 or associated Tier 2 boring location indicate that MCLs, PRGs, or other action levels of the COPCs are not exceeded, then no further investigation will be recommended for groundwater at that location. • If the results of the groundwater sample collected at a specific Tier 1 or associated Tier 2 boring location indicate that MCLs, PRGs, or other action levels of the COPCs are exceeded, then the results will be evaluated for possible Tier 3 groundwater sampling at that location. • If Tier 3 groundwater sampling is considered necessary at a specific Tier 1 or associated Tier 2 boring location, then the nature and extent of COPCs in groundwater will be assessed at that location. • If the nature and extent of COPCs in soil, soil gas, and groundwater during Tier 1, Tier 2, and/or Tier 3 sampling have been defined, then conduct a BHHRA. • If results of the BHHRA indicate that the wastewater pipeline does not pose an unacceptable risk to human health and environment, then recommend the wastewater collection lines for NFA. • If results of the BHHRA indicate that the wastewater line does pose an unacceptable risk to human health and environment, then evaluate the wastewater collection lines for remedial action.
6	Limits on uncertainty.	Step 6 specifies the tolerance limits for decision errors, which are used by the decision makers to establish performance goals for the data collection design. The sampling design was judgmental and based on resources and study objectives. Therefore, no statistical limits on uncertainty have been specified.

Table I. Summary of Data Quality Objectives for Domestic and Industrial Wastewater Lines (continued)

Step	Process	Response
7	Optimize the design.	The sampling design was developed utilizing a modified Triad approach to optimize resources, generate relevant data, resolve open issues, and satisfy the study DQOs. Historic site activities, previous site investigation results and regulatory input were used to guide and formulate the sampling plan. A tiered sampling approach was used for the study. This tiered approach was applied to 10 defined industrial and domestic wastewater line segments that were sampled. The three Tiers are described below. Tier 1 is the initial sampling. The media sampled (soil, soil gas, and/or groundwater), and the soil boring depth, will depend on the depth to groundwater and the depth of the wastewater line at each location. Borings were drilled to depths ranging from approximately 17 to 84 feet bgs. In most cases, borings were located at documented breaks in the wastewater collection lines, or at junctions or bends in the wastewater collection lines, down-flow of facilities that may have discharged industrial wastes. These locations in the wastewater collection lines were the most likely to have leaked wastes to soil or groundwater. Sample analyses for the Tier 1 samples were based on the potentially discharged wastes upstream. Tier 2 was defined as further assessment of vadose (unsaturated) zone soil via collection of soil and/or soil gas samples. Tier 2 would be implemented if contamination is detected during Tier 1 sampling. Tier 3 is defined as further assessment of groundwater via collection of discrete groundwater samples. Tier 3 will be implemented if groundwater contamination is detected in a Tier 1 or Tier 2 initial groundwater sample for a particular location. As soil analytical data became available the sampling plans for the site were optimized. The tiered sampling approach used was an iterative process that involved review of data, conclusions that might be made from the data, input from all involved parties, which permitted data from one tier to be evaluated prior to the implementation of the next tier. In this way, the investigation was optimized by performing the least amount of sampling and laboratory analysis necessary to assist the decision making process about future actions.

Acronyms/Abbreviations:
bgs – below ground surface
BHHRA – baseline human health risk assessment
CCTV – closed circuit television
COPC – chemical of potential concern
DQO – data quality objective
μg/L – micrograms per liter
MCL – maximum contaminant level
NCP – National Oil and Hazardous Substances Pollution Contingency Plan
PCB – polychlorinated biphenyls
PRG – preliminary remediation goals
SVOC – semi-volatile organic compound
TCE – trichloroethene
VOC – volatile organic compound

The Triad Team then subdivided the waste lines into 24 manageable segments to facilitate sampling and evaluation. By collectively evaluating all the pertinent factors with state and federal representatives, 14 pipe segments were recommended for no further action and 10 pipe segments were targeted for sampling during the RI. These 10 pipe segments were then grouped into 7 Units based on location and waste flow characteristics, after sampling, to facilitate sampling, data evaluation and risk assessment (Table II and Figure 3).

Table II. Seven Units Established to Investigate Domestic and Industrial Wastewater Collection Lines

Segment	COPCs (estimated pipe depth)	Upflow Segment(s)	Strategy for RI	Summary of Strategy Rationale
Unit 1 – DS1 and IS1				
DS1	VOCs (>10 feet bgs)	DS3 through DS17 (All DS segments except DS2)	Combine DS1 with IS1 to form CAOC 10.38/10.39 Unit 1.	Both line segments run side by side their entire length. Both segments receive flow from all respective upflow segments except DS-2 for the DWC lines.
IS1	VOCs SVOCs PCBs Pesticides (8 feet bgs)	IS2, IS3, IS4	Combine DS1 with IS1 to form CAOC 10.38/10.39 Unit 1.	Both line segments run side by side their entire length. Both segments receive flow from all respective upflow segments except DS-2 for the DWC lines.
Unit 2 – DS3 and IS2				
DS3	VOCs SVOCs PCBs (15 feet bgs)	DS4, DS5, DS6, DS7, DS8	Combine DS3 with IS2 to form CAOC 10.38/10.39 Unit 2.	Both line segments run side by side their entire length and feed into DS1 and IS1, respectively.
IS2	VOCs SVOCs PCBs Pesticides (12 and 8 feet bgs)[b]	IS3	Combine DS3 with IS2 to form CAOC 10.38/10.39 Unit 2.	Both line segments run side by side their entire length and feed into DS1 and IS1, respectively.
Unit 3 – DS9				
DS9	VOCs SVOCs (5 feet bgs)	None	Address separately as CAOC 10.38/10.39 Unit 3.	No upflow lines.
Unit 4 – DS11 and IS4				
DS11	VOCs SVOCs PCBs (9 feet bgs)	DS12, DS13, DS14, DS15 (possibly DS4 and DS9 connections uncertain)	Combine DS11 with IS4 to form CAOC 10.38/10.39 Unit 4.	Both line segments run side by side their entire length.
IS4	SVOCs PCBs (5 feet bgs)[c]	None; line was never active.	Combine DS11 with IS4 to form CAOC 10.38/10.39 Unit 4.	Both line segments run side by side their entire length.

Table II. RI Strategy for Domestic and Industrial Wastewater Collection Lines (continued)

Segment	COPCs (estimated pipe depth)	Upflow Segment(s)	Strategy for RI	Summary of Strategy Rationale
Unit 5 – DS12				
DS12	TAL metals	DS13 (Housing Area)	Address separately as CAOC 10.38/10.39 Unit 5.	Upflow of everything except housing. Sampling conducted at only known break.
Unit 6 – DS14				
DS14	VOCs SVOCs PCBs (6 to 10 feet)[c,d]	None	Address separately as CAOC 10.38/10.39 Unit 6.	No upflow lines.
Segment	**COPCs (estimated pipe depth)**	**Upflow Segment(s)**	**Strategy for RI**	**Summary of Strategy Rationale**
Unit 7 – DS17				
DS17	VOCs SVOCs (Unknown)[e]	None	Address separately as CAOC 10.38/10.39 Unit 7.	No upflow lines.
Segments Recommended for No Further Action				
DS4, DS5, DS8, DS10, DS13, DS15, DS16	None (NA)	None	Recommend no further action for lines for the CAOC 10.38/10.39 RI.	No known industrial wastes discharged into these lines.
DS6, DS7	None (NA)	DS8	Recommend no further action for DS6 and DS7 for the CAOC 10.38/10.39 RI.	These segments are within the VOC source area being addressed under OU 2.
DS2	None (NA)	None; this segment transmitted wastewater from Old DWTP to CAOC 3.	Recommend no further action for DS2 for the CAOC 10.38/10.39 RI.	No known industrial wastes discharged into these lines.
IS3	VOCs (NA)	None	Recommend for no further action for IS3 for the CAOC 10.38/10.39 RI.	This line segment is in the VOC source area being addressed under OU 2.

Notes:

[a] this column identifies boring locations relevant to define the nature and extent of contaminants for this wastewater collection line segment

[b] pipe depth estimated to be 8 feet bgs at sample location 10.39-IS2-2 and 12 feet bgs at 10.39-IS2-1

[c] pipe depth estimated to be 5 feet bgs at sample location 10.39-IS4-1 and 4 feet bgs at 10.38-DS14-2

[d] pipe depth estimated to be 10 feet bgs at sample location 10.38-DS14-1, 8 feet bgs at 10.38-DS14-3, and 6 feet bgs at 10.20-1

[e] pipe depth unknown; this segment was not investigated as part of the CCTV study and consists of drains and ditches that discharged to storm drains

Acronyms/Abbreviations:

- bgs – below ground surface
- CAOC – Comprehensive Environmental Response, Compensation, and Liability Act area of concern
- CCTV – closed-circuit television
- COPC – chemical of potential concern
- DS – domestic sewer
- DWC – domestic wastewater collection
- DWTP – domestic wastewater treatment plant
- ERFA – extended Resource Conservation and Recovery Act facility assessment
- IS – industrial sewer line segment
- NA – not applicable
- OU – operable unit
- PCB – polychlorinated biphenyl
- RFA – Resource Conservation and Recovery Act facility assessment
- RI – remedial investigation
- SVOC – semivolatile organic compound
- TAL – target analyte list
- VOC – volatile organic compound

Fig. 3. Unit designations for wastewater collection lines

The Triad Team then chose sampling locations at major documented pipe breaks located closest to and downflow of past discharging facilities (the most likely release points). In order to spatially characterize the nature and extent of contamination at each sampling location, the Triad Team chose a tiered sampling approach (Figure 4). If the results of a vadose zone (soil or soil gas) sample from a Tier 1 boring at a specific location indicated an exceedance of a contaminant of a COPC screening level, then the results were evaluated for possible Tier 2 vadose zone and/or groundwater sampling at that location. Results exceeding levels after Tier 2 sampling at that location, if conducted, were evaluated for potential Tier 3 sampling, and so on. If the Tier 1, Tier 2, and/or Tier 3 sampling sufficiently defined the nature and extent of COPCs in soil and groundwater at a site, then the team conducted the baseline human-health risk assessment. This modified Triad approach greatly reduced investigation costs while still meeting DQOs

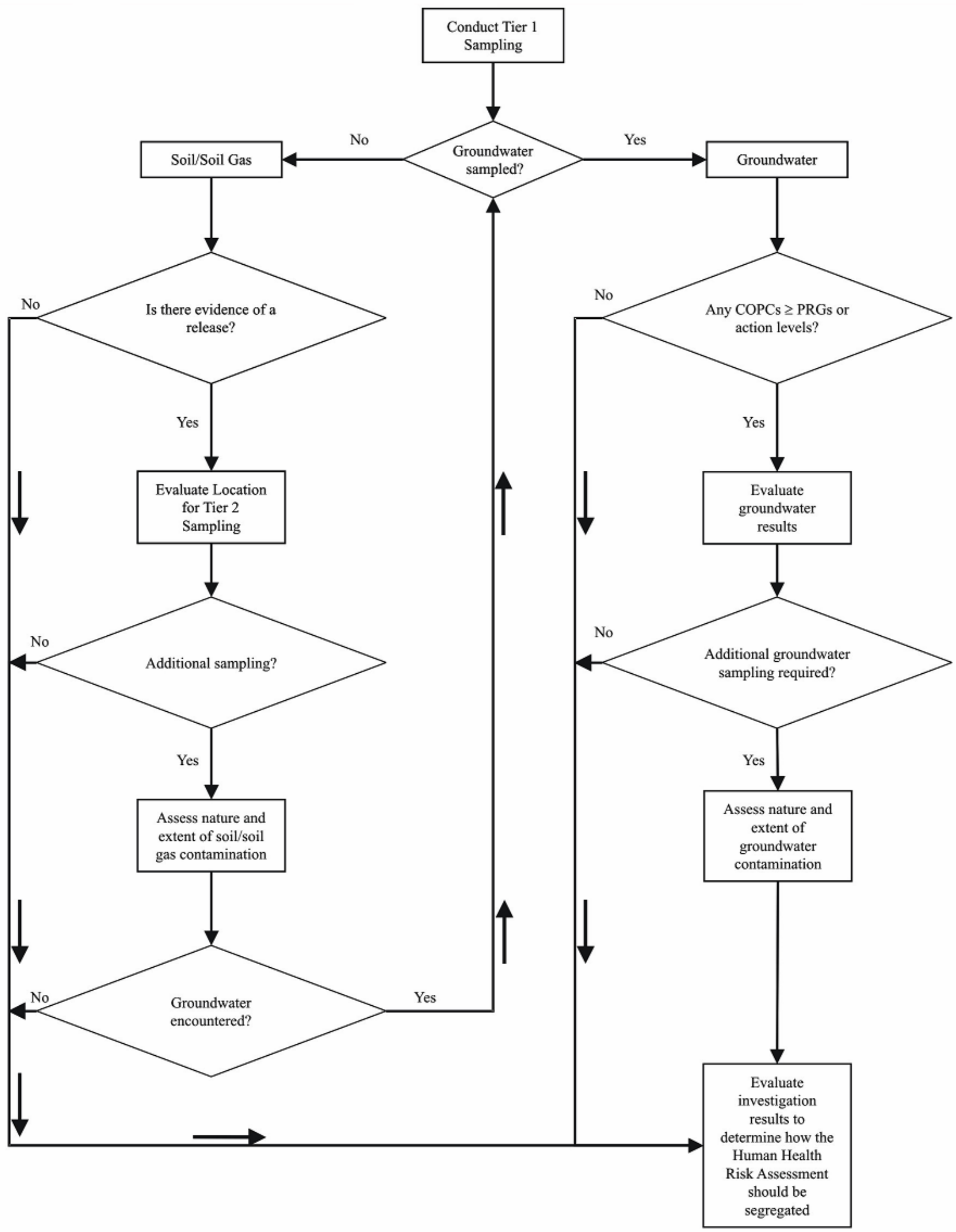

Fig. 4. Flowchart used for tiered sampling approach to determine nature and extent of contaminants of potential concern in soil, soil gas and groundwater

CONCLUSIONS AND RECOMMENDATIONS

A modified Triad approach was used to design and implement a dynamic and defensible RI sampling and analysis work plan for characterizing COPCs that may have leaked from wastewater lines at an active military Base. The primary objective was to investigate and define COPCs in soil, soil gas, and groundwater that may have been sourced from domestic and industrial wastewater lines. The secondary objective was to accomplish this task efficiently and cost effectively.

The investigation was implemented using a variety of tools. The data collected during the RI proved sufficient to characterize the nature and extent of contamination, perform a baseline Human Health Risk Assessment, and support decisions on the necessity for remedial actions related to leakage from the wastewater lines. The outcome resulted in no further action recommendations for Units 1 though 6. Groundwater was recommended for further investigated at Unit 7.

Conducting an RI using modified Triad approach, shortened the fieldwork duration, sampling and analytical costs. The method was successful because of the close cooperation and involvement of the Triad Team that consisted of members representing the Navy, federal and state regulators, and Bechtel National, Inc.

REFERENCES

1. EPA, 2000, Guidance for the Data Quality Objectives Process, EPA QA/G-4. August.