Engineering Report

POTABLE WATER
Distribution System Analysis

Croton-on-Hudson (V)
Westchester County, NY

March3, 2006

THE Chazen COMPANIES

Prepared for:

Village of Croton-on-Hudson
One Van Wyke Street
Croton-on-Hudson, NY 10520

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1.0 INTRODUCTION

The Village of Croton-on-Hudson (Village) operates a public water supply system within Westchester County, permitted by the New York State Department of Health (PWS ID# NY5903425). The Village of Croton-on-Hudson's main water source is a well system located approximately 4,000 feet downstream from the New Croton Dam and spillway. Water is pumped directly from the well field into the distribution system, which consists of a network of water mains, four storage tanks (reservoirs), pumps, booster pump stations, and other water-related infrastructure. The village's total storage capacity is 2.3 million gallons. There are currently no restrictions on the Village's water source.

1.1 Service Area Description

The Village water system supplies approximately 7,600 people, primarily in residences but also in businesses and industries, with 2,500 service connections. During 2004, the total amount of water withdrawn from the aquifer was approximately 382 million gallons. The daily average volume of water treated and pumped into the distribution system was 1.04 million gallons per day. Approximately 90% of the total was billed directly to consumers. The balance, or unaccounted for water, went to firefighting, hydrant use, leaks in the distribution system, and unauthorized use.

The Village's service area is divided into two operational zones: the larger lower zone, which includes the older center of the Village, and an upper zone that serves the relatively newer area of the Village. The lower zone is supplied directly from the source wells or from the large Highland storage tank. The Upper zone is supplied from the Hessian Hills tank, which is feed from the Highland booster pump. The Village supplies the golf course, which has a substantial water demand for irrigation during the summer, from the Highland booster pumps through the Golf Course Tank. Figure 1 presents an aerial map of the Village showing the major components of the water system.

1.2 Distribution System Description

The Village's water distribution system is comprised of a mixture of pipe material of varying age, typical of older systems that have been expanded over a period of time. The distribution mains within the system are unlined cast iron, and cement lined cast and ductile iron pipe. Lesser quantities of water distribution mains in the system are galvanized steel, asbestos cement, and copper.

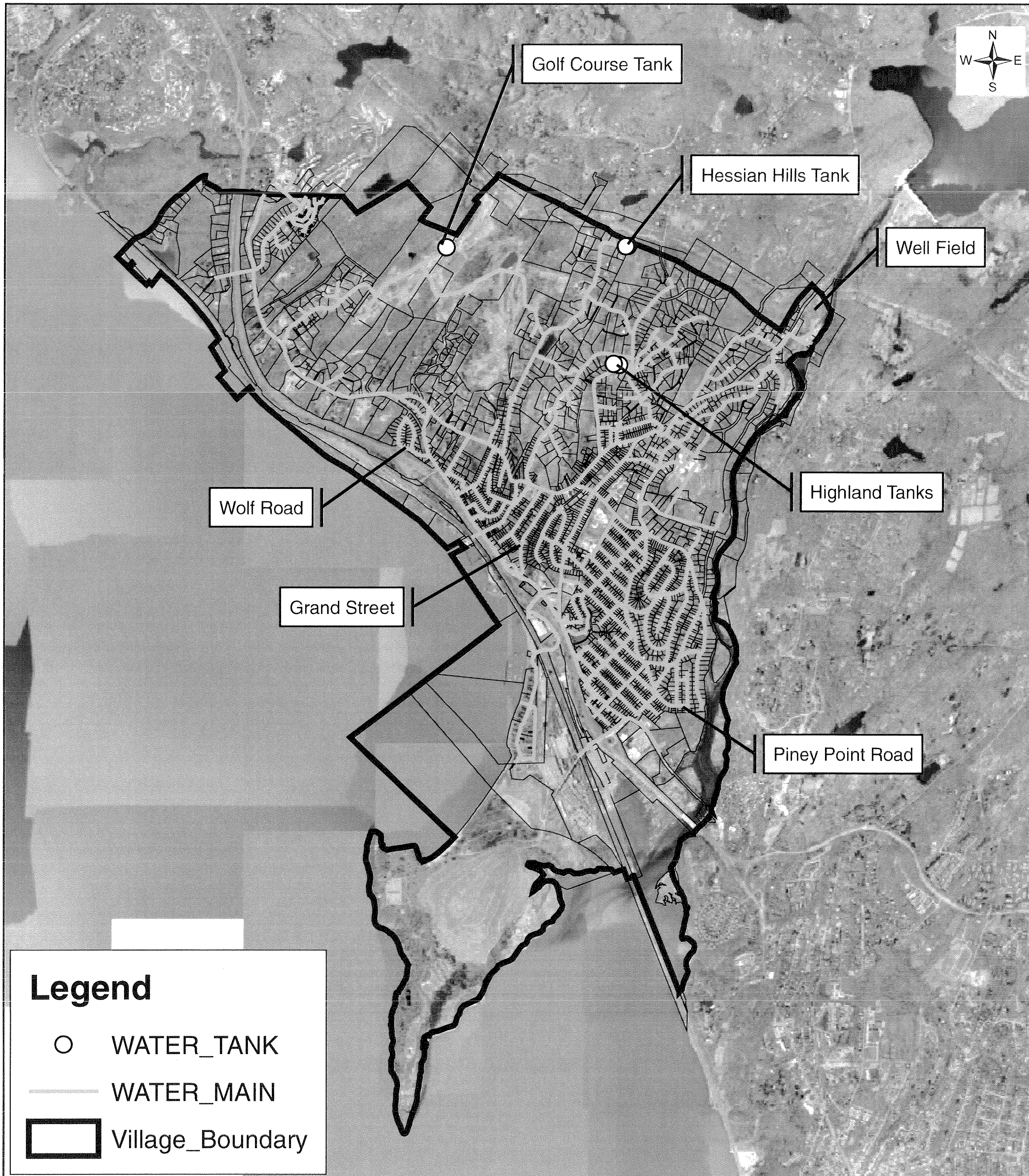

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FIGURE 1 - LOCATION MAP
Village of Cronton-on-Hudson
Westchester County, New York

NYS Office of Technology 2004 Orthophoto Data

Created by: Sharon Froedden
Date: January 2006
Scale: 1 in equals 3,001 ft
Project #: 40408.00

The older water distribution pipes are generally located in the lower portion of the water service area, which includes the older areas of the Village. As indicated by the Village Water Department staff, this lower portion of the distribution system has the highest rate of "brown" water complaints.

There are four water storage tanks used to maintain system pressure and provide fire protection flow within the distribution system. Two of the tanks (the large Highland Tank and the Hessian Hills Tank) provide the majority of usable storage capacity in the system while the other two tanks (the smaller Highland Tank and the Golf Course Tank) are used primarily to supply booster pump systems.

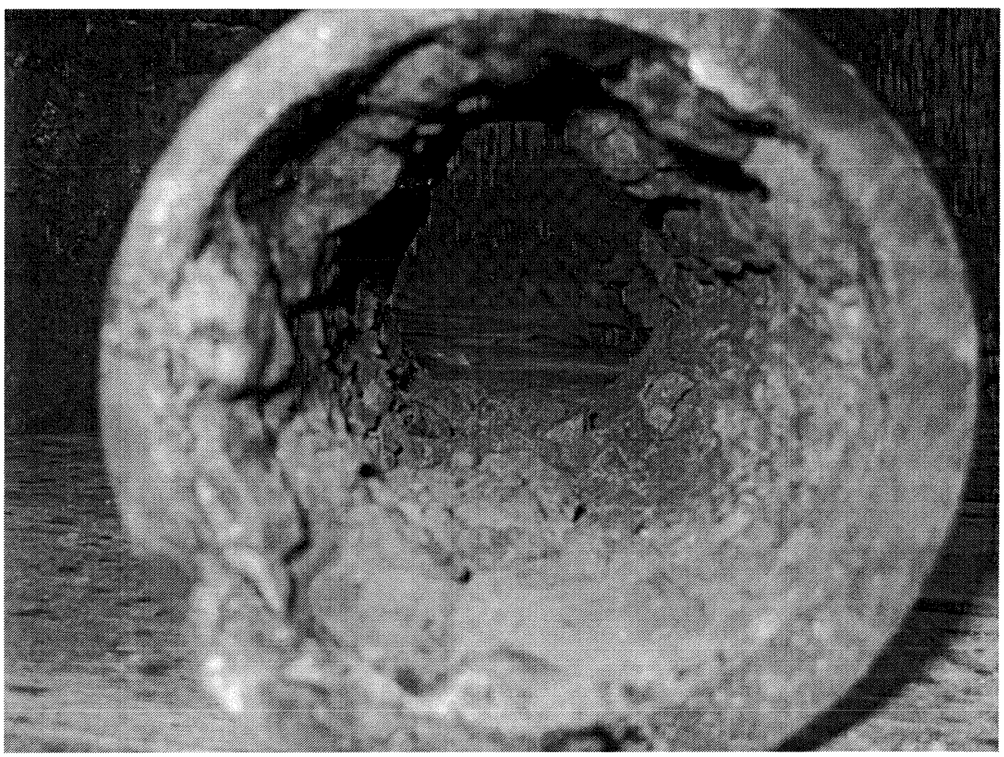


Figure 2 - Photographic example of unlined cast iron pipe Taken from the watermain replacement project in the Village

2.0 SAMPLING PROGRAM

2.1 Sampling Program Description

The Village Water Department regularly performs the requisite sampling at the specified time intervals, as stipulated in NYSDOH Part 5, Subpart 5-1, *Public Water Systems,* for the Village water supply system. The results of the regularly mandated sampling are presented in a summary format in the Annual Report of the Village Department of Water, last issued December 2004.

In addition, to support this evaluation effort, the Village has acquired and analyzed additional samples from the water supply wells and locations within the distribution system. Also, TCC performed field measurements of several water quality parameters within the Village's Highlands and Hessian Hills water storage tanks. Comprehensive tabular results for the sampling conducted under this project are presented in Appendix A.

A brief summary of each sampling effort is presented in the sections below.

The sampling data acquired at the wellhead sites is summarized in Table 1 below. Individual sampling parameters are discussed here.

- Alkalinity plays a complex role in corrosion of pipes. The alkalinity concentration affects the stability of dissolved and solid species within the water, the kinetics of reactions, and, importantly, is an indication of water's ability to resist changes in pH.

- Lower pH values (pH< 7, acidic) indicate an increased degree of likelihood that a water supply will have difficulty in complying with the EPA Lead and Copper Rule (LCR). Acidic water causes an increase in leaching of lead and copper from the walls of unlined pipes.

- Total Dissolved Solids (TDS) are an indicator of water palatability. The particular solids present in a water supply affect the impact of TDS on water quality.

- Turbidity is a measure of the clarity of a water supply. Higher turbidity values indicate cloudy, less acceptable water and the presence of solids and/or dissolved materials.

- The presence of metals in the water supply is not unexpected, particularly for well water. However, elevated concentrations may be indicative of distribution system pipe issues and a corrosion-favorable environment.

- Temperature has a significant impact on the rate of chemical reactions and the likelihood of biological activity. The higher the temperature, the more rapidly reactions will occur.

- Specific conductivity is interrelated to TDS. Water having a high TDS concentration will also likely have a high specific conductivity.

Table 1: Sampling Parameters

Sampling Parameter	Units
Chemistry Parameters	
Alkalinity as Calcium Carbonate ($CaCO_3$)	mg/L(1)
pH	pH Units
Total Dissolved Solids (TDS)	mg/L
Physical Parameters	
Turbidity	NTU(2)
Metals	
Calcium (Ca)	mg/L
Iron (Fe)	mg/L
Magnesium (Mg)	mg/L
Manganese (Mn)	mg/L
Dissolved Metals	
Iron (Fe)	mg/L
Manganese (Mn)	mg/L
Field Parameters	
Temperature	° C(3)
Specific Conductivity	uS/cm(4)

(1) milligrams/Liter
(2) Nephelometric Turbidity Units
(3) degrees Centigrade
(4) microSiemens per centimeter

2.1.1 Supply Well Sampling

The Village collected samples at the wells and within the water distribution system on May 9, June 16, July 21, August 11, and September 15, 2005.

The Village Water Department collected the supply well samples at the combined flow from the well field as it entered the distribution system.

2.1.2 Distribution System Sampling

The three (3) distribution system samples were collected from fire hydrants located at Grand Street, Piney Point Road, and Wolf Road, as shown on Figure 1.

The Village Water Department collected samples within the distribution system on the same dates as the well sampling (May 9, June 16, July 21, August 11, and September 15, 2005). The constituents noted in Table 1 were also analyzed for the samples taken from the distribution system.

2.1.3 Tank Water Quality Measurements

Field water quality measurements from within the Highlands and Hessian Hills storage tanks were made by TCC on October 6 and November 3, 2005. The goal of this effort was to develop a vertical profile of water quality through the full depth of the tanks. Although the plan was to take measurements from all four tanks, it was determined after evaluating the available tank access points with the Village Water Department, that two of the tanks would not be suitable. The smaller Highland Tank was inaccessible for measurements, and the Golf Course tank was isolated from the rest of the water distribution system by a one-way valve. Therefore, only the larger Highland tank and the Hessian Hills tank would be evaluated.

The larger Highland Tank had two man-way access hatches, one on the southwest side where the tank is exposed to environmental changes in temperature, and one on the northeast side, which is partially buried in the hill. Since these two accesses points are horizontally separated by approximately 75 feet, and exposed to differing levels of environmental temperature change, field measurements were made at both locations to determine if there were horizontal variations in water quality as well.

Field measurements collected within the tanks included: temperature, specific conductivity, dissolved oxygen, and pH. In addition, the oxidation-reduction potential (ORP) was also measured in the two tanks. The ORP indicates the potential for a particular type of chemical reaction to occur in which one species loses elemental oxygen and a second species acquires the oxygen; corrosion processes are one of these reactions.

2.2 Sampling Program Results

A complete set of the sampling results are presented in the tables included in Appendix A. Sampling results are discussed in the sections below.

2.2.1 Wellhead Sampling

The Village Water Department collected samples from the supply wells on the five (5) dates noted above, which were analyzed for the parameters listed in Table 1 above.

In general, sampling results at the wells indicates that the Village water supply is of a good quality. The raw water pH value is nearly optimal, alkalinity is on the low side, and total dissolved solids are well within the recommended limit. The concentration of metals and dissolved metals are well within applicable limits.

The water temperature indicated for the supply well samples is slightly higher then expected. A higher temperature aids in increasing the rate of chemical reactions within the distribution system; some of which are inevitably corrosion reactions.

2.2.2 Distribution System Sampling

The Village Water Department collected samples within the water distribution system on the same five (5) dates that the supply wells were sampled. As with the supply well samples, the distribution system samples were also analyzed for the parameters listed in Table 1 above.

Sample results from the distribution system have similar values to those from the wells, except higher concentrations of iron was observed at the Piney Point Road and Wolf Road sampling points. At Wolf Road, iron concentrations greater than 4 mg/L were obtained, while iron concentrations of up to 46 mg/L (150 times the limit) were found on Piney Point Road. The maximum allowable concentration of iron is 0.3 mg/L.

These Iron concentrations found within the distribution system, which are higher than those indicated in the Wellhead samples, are indicators of corrosion occurring within the distribution system pipes. Tuberculation from the inner wall of the pipes (as shown in Figure 1) is likely being conveyed through the system. Higher flow velocities within the pipe causes' turbulent flow, particularly within the more heavily tuberculated pipes, which can cause oxidized iron to be scoured from the pipe surface and conveyed through the system in a process termed erosion corrosion.

2.2.3 Tank Water Quality Measurements

TCC staff made Field water quality measurements of two of the Village's water storage tanks in October 6th and November 3,rd of 2005. Sampling was done at both access points on the Highland Tank. Data was collected at two (2) foot increments of depth from the water surface to the bottom of the tanks.

Field water quality measurements at the Hessian Hills Tank yielded no unexpected results. Measurements were all within the normally expected ranges.

Field water quality measurements from the larger Highland Tank yielded some observations of interest. The dissolved oxygen (DO) concentration in the tank is unusually low and drops with increased depth within the tank. Usually, because an increase in pressure allows for higher DO concentrations, the oxygen concentration would be expected to increase slightly with depth. The drop in DO concentration with depth in the tank may indicate the presence of chemical and/or biological processes that are occurring in the tank and consuming oxygen. Appendix A includes a tabular data summary as well as graphs of some variables of interest for the Highland Tank.

The redox potential (ORP) in the Highland Tank also varies significantly with depth; initially ORP increases with depth, and then ORP droops sharply near the bottom of the tank. One possible reason for this is chemical and/or biological processes occurring in the tank until available DO is depleted. This may be an indication of excessive water age or stagnation in the water tank.

Some horizontal variation was observed within the large Highland Tank. Most notably the ORP was approximately 10 % higher at Sample Point 2 (the southwest portion of the tank). There were also less pronounced differences between the water temperature and dissolved oxygen reading s from the two sampling points within the Highland Tank. These differences may be an indication of incomplete mixing in the tank, or a result of the differences in exposure to environmental temperature changes between the exposed and buried portions f the tank.

3.0 RECOMMENDATIONS

3.1 Corrosion Control Program

It is recommended that a corrosion control program be initiated. The addition of a corrosion control chemical to the distribution system would aid in the reduction of brown-water events and also reduce lead concentrations in the system. The 2004 annual report of the Village Department of Water indicates that the 90^{th} percentile lead concentration is nearing the allowable limit.

The Village would benefit by being pro-active regarding lead concentrations. If a violation occurs, the Village would be required to implement a corrosion control program and would also be required to sample for lead far more often than currently required. The cost of additional sample collection and analyses for lead and copper would be significant.

3.1.1 Corrosion Control Program Description

It is proposed to add a form of liquid zinc orthophosphate [$Zn_3(PO_4)^2$] to the water supply. The zinc will bind to the inner wall of the pipe and, to some degree, isolate the pipe from the water. The zinc orthophosphate would be injected into the distribution system at a point near the well field.

Zinc orthophosphate is a commonly used chemical for corrosion control. It has no deleterious health effects. The form of zinc orthophosphate proposed to be added to the water supply is NSF approved and will be readily acceptable to regulators reviewing the proposed program.

Initially, it is recommended by the chemical supplier to add the zinc orthophosphate at a slightly higher than required concentration to facilitate the initial coating of the water distribution piping interiors. The distribution system will be monitored, and after an initial period the dosage will be decreased to a more normal level.

3.1.2 Corrosion Control Limitations

Corrosion control additives can be expected to limit corrosion of pipes and the leaching of copper and lead into the water column. However, corrosion is a complex process, influenced by many factors. Particularly for pipes already having severe tuberculation, it can not be guaranteed that a corrosion control additive will completely eliminate brown -water events.

The addition of a corrosion control additive to the water supply causes favorable changes to the system with respect to the water condition. The additive also can have less favorable impacts on other important water quality parameters, most notably the pH and chlorine residual. These parameters will require additional monitoring during the early implementation of a corrosion control system.

3.1.3 Long-term Monitoring Requirements

The addition of a corrosion control additive requires more careful monitoring of the distribution system water quality. Some items of concern include:

1. pH – addition of a corrosion control additive results in a minor reduction in the pH value. That is, the addition of the additive results in slightly more acidic water. More acidic water has impacts on other aspects of water quality. In itself, an increase in the acidity of the water increase the lead and copper leaching into the water supply.

   The pH value also has some bearing on the efficacy of the corrosion control program. The corrosion control additive works best for a pH in the range of 7.2-7.6. Lower pH values reduce the efficiency of the additive. Higher pH values can cause the zinc to precipitate. If the zinc precipitates, it will be observed by the consumer as small black flakes in the water. Consumer complaints would be likely if zinc were to precipitate from the water supply. As it is proposed to start the corrosion control program with a higher than required concentration of the additive, it will be crucial for the Water Department to monitor the water pH throughout the entire distribution system.

   It is anticipated that the pH in the distribution system will be lower than the optimal range noted above. At this time it is not proposed to also use a second additive to boost the pH. However, this should be re-evaluated after initial post-corrosion control program initiation sample data is available.

2. The addition of the corrosion control additive may also require that the disinfection dosage be increased. The additive will cause the chlorine residual to drop slightly. The Water Department will also need to carefully monitor the chlorine residual throughout the system.

3.1.4 Corrosion Control Costs

At this early conceptual stage the probable cost of implementing a corrosion control system is difficult to accurately predict. A bench test of the Village's water with various corrosion control additives should be completed to initially identify the most effective additive and dose. When completed, the bench test results would be used to select the necessary equipment, which will indicate the size and type of location needed to house the equipment.

The capital costs associated with the implementation of a corrosion control system would include the purchase and installation of a flow-paced metering pump and chemical storage units. Additionally, if the Village's well field meters can not provide an output signal compatible with the metering pump, a new meter will need to be purchased. The corrosion control additive is somewhat vulnerable to lower temperatures, and it would be recommended that the building in which this system is housed be maintained at a temperature above 50° F.

The corrosion control system might be housed in the existing Water Department office located at the Village's well field. This building is in close proximity to the main transmission line leading to the water distribution system. This existing building is heated and has existing electrical power. However, the compatibility of the corrosion control system with the current use of this building needs to be evaluated with regard to available space, safety, and other potential issues.

Alternately, the Village could erect a small equipment shed across the service road from the Water Department's well field office to house the metering pump and chemical storage units. This would require the additional expense of the equipment shed and the extension of electrical power for both the metering pump and a unit heater.

Operation and maintenance costs would include the cost of the corrosion control additive, electrical power costs, additional monitoring costs, preventative equipment maintenance, and periodic repairs. Initially, the estimated chemical cost would be approximately $30/day. Once the initial coating of the pipe interiors has occurred, as determined through system monitoring, the chemical concentration would be reduced and the chemical cost lowered o an estimated $20/day. The other operational costs would be approximately equal to the chemical cost.

Conceptual Corrosion System Cost		
	Using Existing Building	**New Equipment Shed**
Equipment Capital Costs(1)	$5,000	$5,000
Equipment Housing (2)	$1,500	$5,000
Annual O & M Costs (3)	$18,250	$21,900

(1) Does not include a new flow meter

(2) Modifications to existing building or new equipment shed with power

(3) Based on a total of $50/day if located in existing heated, and $60/day if located in separate equipment shed.

3.3 Highland Storage Tank Modifications

Based on the water quality measurements taken from within two of the Village's storgae tanks, combined with anecdotal information obtained from the Village Water Department, it appears that the Large Highland Tank may be experiencing excessive water age or stagnation. The water quality measurements indicate the water quality in the large tank varies significantly with depth, and below expected results. Additionally, the Water Department indicated that during periods in the summer the water temperatures in the lower portion of the water distribution system, which are feed from the Highland Tank, become elevated. This suggests that the water is sitting in the tank, which has an exposed southern face, without sufficient mixing and becoming heated.

The potential for stagnation in this tank is further confirmed by a review of the available design drawings for the Highland Tank, the General Plan of which is included in Appendix B. The tank, designed in 1964, has a single 12" diameter inlet/outlet pipe located in the southwest portion of the tank. This combined with the large storage volume relative to daily demand limits the amount of mixing that would be expected under normal operation. It has been shown that without thorough mixing the water within even moderate sized storage tanks can become stagnant under normal operation. Then, during a period of high peak demand such as a fire flow, pipe burst, or heavy irrigation flow the stagnant water can be released into the distribution system creating a period of reduced water quality and increased customer complaints.

As a follow up to this initial evaluation the Village should consider operational and/or equipment modifications to the Highland Tank.

- These may include altering the level in the tank to reduce the water storage volume. However, since the storage volume in the tank is dictated by fire protection requirements, the Village Water Department has indicated there is minimal ability to fluctuate the tank level.

- Consider installing an extended inlet/outlet pipe that would project across the floor of the tank. This new pipe section could be equipped with a series of oriented uni-directional diffuser ports that would promote mixing within the tank during normal operation. Red Valve, Inc. markets flexible duck-billed valves that can be fitted to an extended inlet/outlet pipe in such a manner, and has had reported success in improving storage tank water quality.

- Evaluate the option of installing a recirculation line from the Highland Booster Pump to the northeast portion of the tank to allow for periodic mixing. A control unit could divert flow into the Highland Tank after receiving a high level cutoff at the end of a fill cycle for the Hessian Hills tank. This would provide a minimal level of burst mixing in the tank to improve water quality. Alternately, a separate recycling pump could be added to help keep the larger Highland Tank "fresh",

- In addition to these potential modifications, the Village should also consider having the Highland Tank cleaned of sediments. Although no measurement of thickness was made, a sediment layer was noted during the storage tank water quality measurement exercise. This sediment layer agitated during periods of high demand, potentially releasing suspended solids into the water distribution system.

3.3 Distribution System Maintenance

There are also several alternatives available to the Village that may both extend the service life of the water distribution system and reduce the frequency of "brown" water complaints. A detailed evaluation of the potential of these maintenance alternatives is beyond the scope of this project, therefore, only a brief description of the alternatives that may be considered by the Village in the future is presented.

Mechanical cleaning physically cleans the interior surfaces of pipe to remove buildup that results from either sedimentation or corrosion. Mechanical cleaning can be accomplished using a series of "pigs" or shaped scrubbers placed in the watermain and driven by upstream water pressure to scrub the inside of the pipes. Pigs may be launched, and recovered, from disassembled fire hydrants

Another form of mechanical cleaning utilizes a chain of metal scrappers that are either pushed through a pipe hydraulically, or pulled through a pipe using a winch. Metal scrappers can remove large amounts of heavy solids in a single pass, however, both type of scrapper require that an entry and exit point be cut into the water main.

Chemical cleaning uses a liquid cleaning agent, targeted to the type of deposits found in a pie, to dissolve and breakdown the solids. To use chemical cleaning a section of watermain is isolated, the cleaning solution introduced and allowed to react for a period of typically 24 hours. The section of line is then flushed at high velocity to remove the dissolved and suspended solids.

Surface applied pipe Lining is typically used following a program of heavy cleaning to remove severe corrosion in order to minimize the reoccurrence of corrosion. Once the pipe section has been cleaned, the pipe can be lined with a cement or epoxy lining, The linings are usually spun cast to the interior of the pipe, providing a corrosion resistant coating that can extend the life of pipe.

Alternately, if a pipe section has a high leakage rate, a structural lining system such as fold-and-form or cured-in-place pipe lining might be considered. These systems differ in how the lining works with the existing pipe to improve structural integrity and eliminate leaks, but the installation method is very similar. A section of pipe is removed and the lining is introduced into the pipe, then the lining is formed to the inside of the original pipe using steam or hot water. Typically the minor loss of interior pipe diameter is compensated by the lower friction losses associated with the lining materials (PVC, HDPE, or Epoxy resins)

In certain instances, such as when distribution piping is beyond it's expected service life and does not have the capacity to meet current or future needs, phased pipe replacement should also be considered as a viable alternative.

Appendix A:
Field Water Quality Measurements

Village of Croton
Storage Tank Water Quality
Sample Date: 10/6/2005

North Highlands Above Ground Tank - Sampling Point No. 1 Water Elevation at Time of Sampling: 22.9'

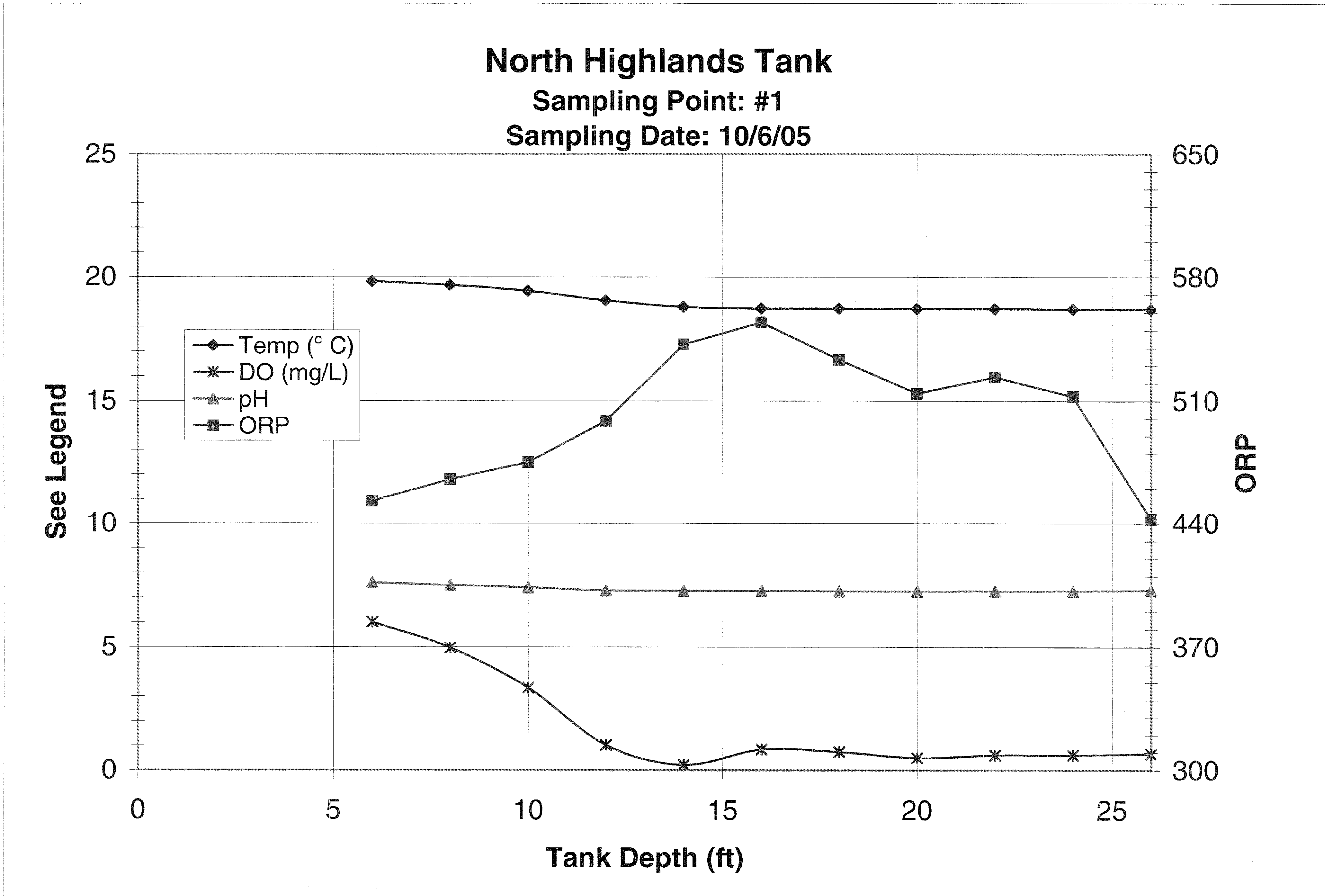
	Depth in Feet (approximate)										
Parameter	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**
Temp °C	19.82	19.66	19.43	19.05	18.79	18.74	18.74	18.73	18.73	18.72	18.71
mS/cmC	0.41	0.41	0.41	0.407	0.408	0.407	0.407	0.407	0.407	0.407	0.405
Ms/cm	0.37	0.368	0.366	0.361	0.36	0.372	0.359	0.358	0.358	0.358	0.357
DO%	66.4	55.3	36.9	13.9	15.4	9.2	8.2	5.6	3.7	6.8	6.6
DO mg/L	6	4.96	3.35	1.02	0.22	0.85	0.76	0.52	0.63	0.63	0.69
DO ch	67.6	66.5	65.5	62.5	62.5	62.5	62.5	64.5	63.5	62.5	74.7
pH	7.59	7.49	7.40	7.28	7.27	7.27	7.26	7.26	7.27	7.28	7.31
pHmV	-49.2	-43.9	-38.4	-31.2	-30.8	-30.8	-30.5	-30.1	-30.7	-31.5	-32.9
ORP	452.6	465.1	474.8	498.7	542	554.6	533.5	514.3	523.7	512.6	442.7

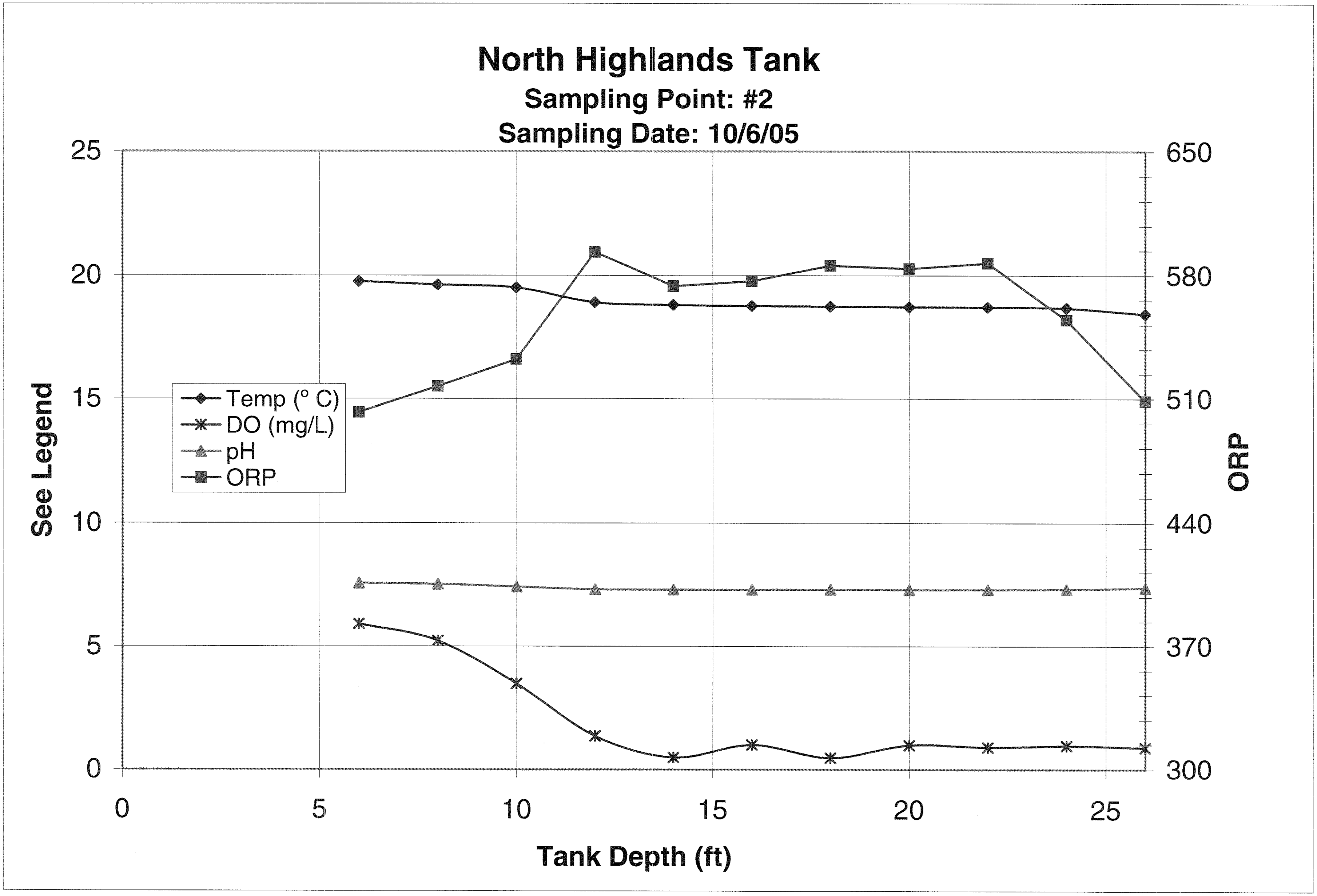
North Highlands Above Ground Tank - Sampling Point No. 2 Water Elevation at Time of Sampling: 22.9'

	Depth in Feet (approximate)										
Parameter	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**
Temp °C	19.75	19.62	19.5	18.91	18.81	18.77	18.75	18.73	18.72	18.70	18.45
mS/cmC	0.409	0.409	0.408	0.407	0.407	0.407	0.407	0.407	0.407	0.407	0.403
Ms/cm	0.368	0.367	0.365	0.360	0.359	0.358	0.358	0.3528	0.358	0.358	0.352
DO%	64.7	53.9	37.9	14.6	7.9	10.7	5.1	10.1	10.1	10.6	10.8
DO mg/L	5.90	5.22	3.47	1.36	0.49	1.00	0.48	0.99	0.91	0.98	0.90
DO ch	60.4	60.4	59.4	57.4	59.4	61.4	61.4	62.5	65.5	71.7	76.8
pH	7.56	7.52	7.42	7.32	7.31	7.31	7.32	7.31	7.32	7.34	7.39
pHmV	-47.8	-44.2	-39.5	-34.9	-33.9	-33.7	-33.5	-33.3	-33.5	-34.9	-37.7
ORP	502.1	516.9	532.3	593.2	573.9	576.9	585.7	583.9	587.1	555.1	508.9

Hessian Hills Tank Water Elevation at Time of Sampling: 11'

	Depth in Feet (approximate)			
Parameter	**6**	**8**	**10**	**12**
Temp °C	18.59	18.59	18.59	18.66
mS/cmC	0.407	0.407	0.407	0.408
Ms/cm	0.358	0.358	0.357	0.359
DO%	79.9	87.3	102.1	136.1
DO mg/L	7.37	8.01	9.54	12.50
DO ch	45.1	46.1	48.2	52.3
pH	7.40	7.42	7.45	7.49
pHmV	-38.2	-39.3	-41.0	-43.6
ORP	411.8	410.4	407.8	404.0


North Highlands Tank
Sampling Point: #1
Sampling Date: 10/6/05
25
20
15
10
5
0
See Legend
650
580
510
440
370
300
ORP
0
5
10
15
20
25
Tank Depth (ft)
Temp (° C)
DO (mg/L)
pH
ORP


North Highlands Tank
Sampling Point: #2
Sampling Date: 10/6/05
See Legend
ORP
Tank Depth (ft)
Temp (° C)
DO (mg/L)
pH
ORP
0
5
10
15
20
25
0
5
10
15
20
25
300
370
440
510
580
650

Village of Croton
Storage Tank Water Quality
Sample Date: 11/03/2005

North Highlands Above Ground Tank - Sampling Point No. 1 Water Elevation at Time of Sampling: 21.5'

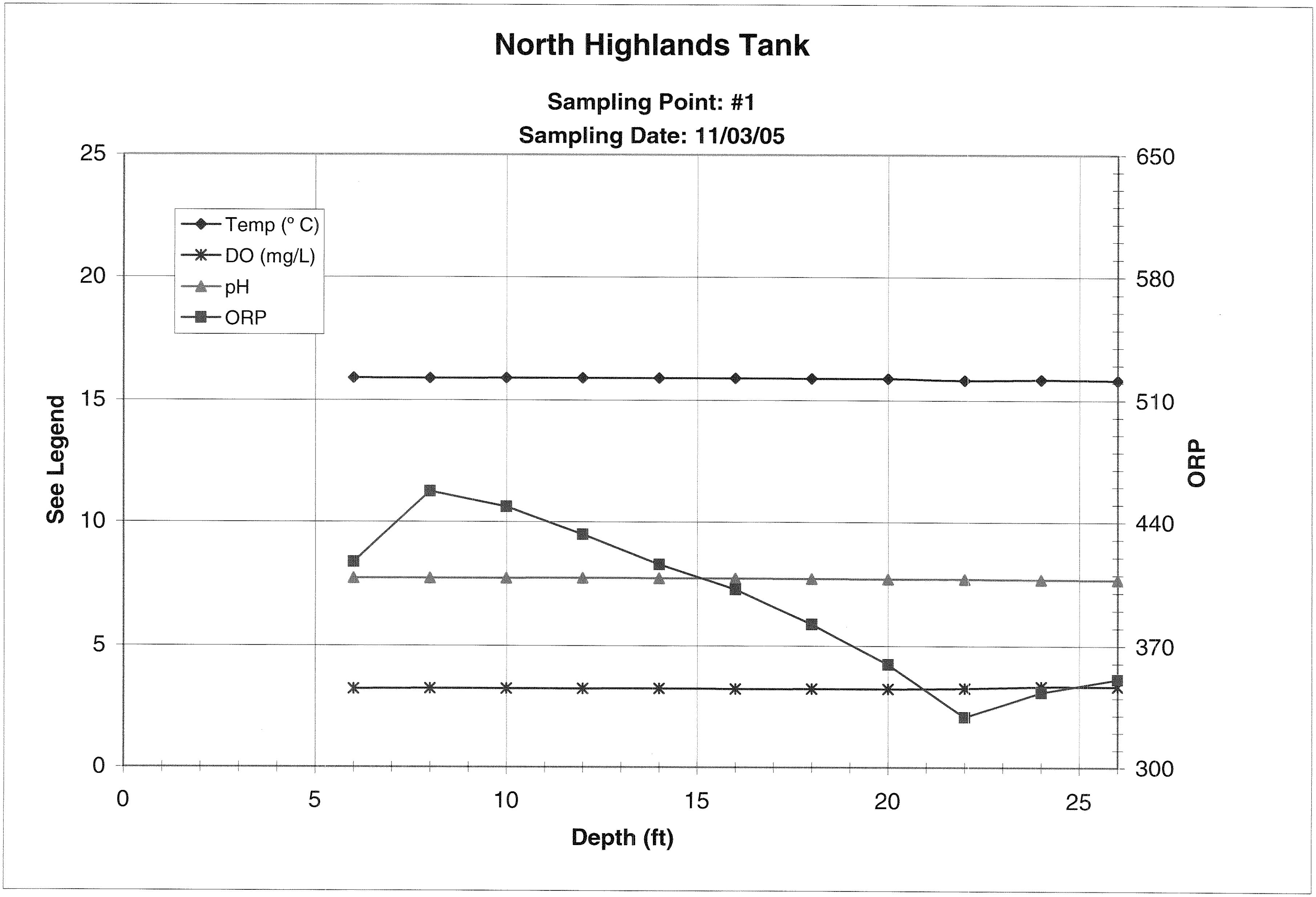
	Depth in Feet (approximate)										
Parameter	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**
Temp °C	15.90	15.89	15.90	15.90	15.90	15.90	15.89	15.89	15.82	15.85	15.82
mS/cmC	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.428	0.425	0.426
Ms/cm	0.352	0.352	0.352	0.352	0.352	0.352	0.352	0.351	0.353	0.351	0.351
DO%	32.5	32.7	32.7	32.7	32.8	32.7	32.8	32.8	32.9	33.9	33.6
DO mg/L	3.21	3.23	3.23	3.23	3.24	3.23	3.24	3.24	3.26	3.34	3.34
DO ch	35.9	35.9	35.9	35.9	35.9	35.9	34.9	34.9	34.9	34.9	34.9
pH	7.71	7.71	7.71	7.72	7.71	7.71	7.70	7.69	7.69	7.67	7.66
pHmV	-48.0	-48.0	-48.2	-48.6	-48.2	-48.3	-47.8	-47.2	-47.1	-46.0	-45.7
ORP	417.0	457.3	448.5	432.7	415.8	401.9	382.3	359.5	329.1	343.4	351.0

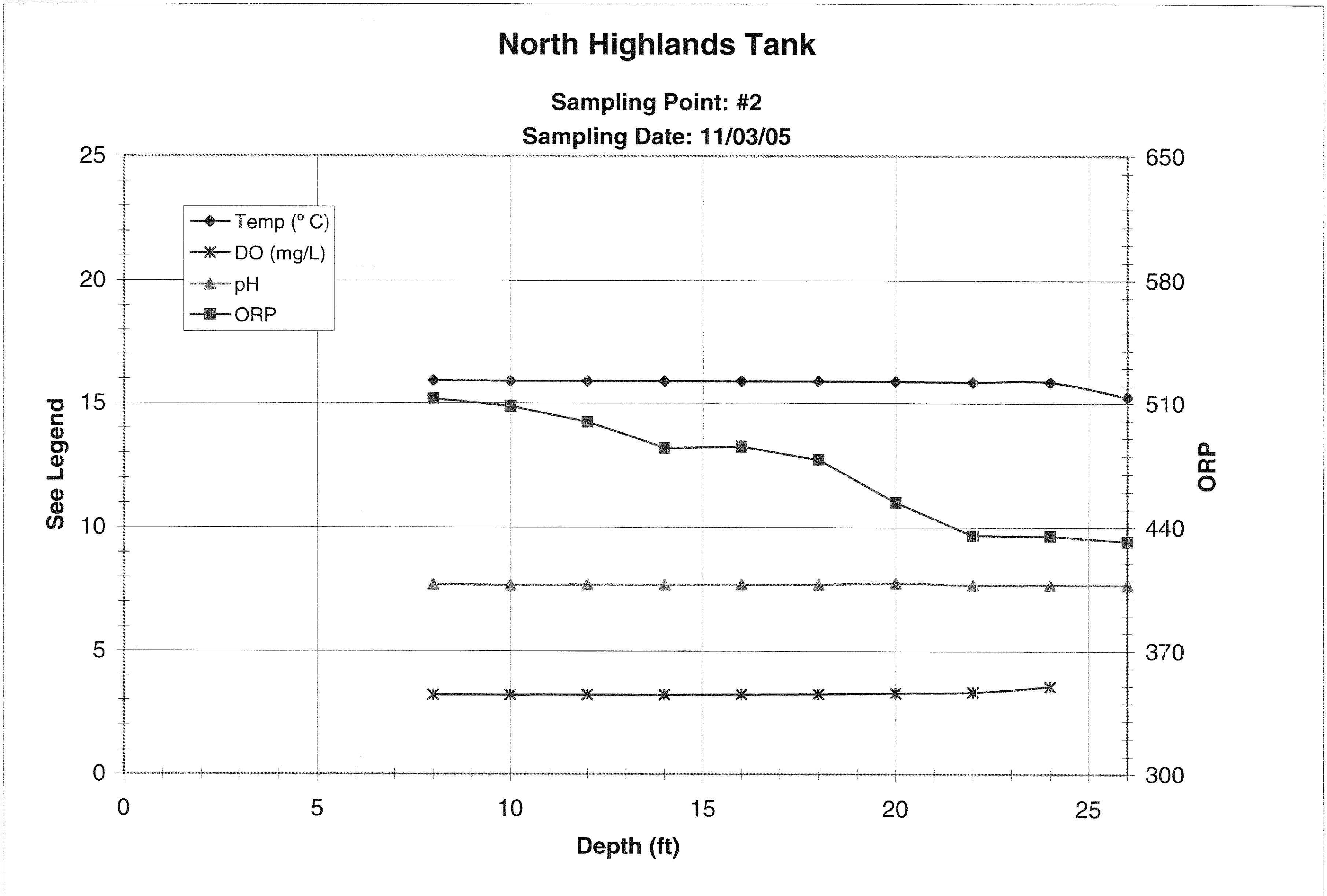
North Highlands Above Ground Tank - Sampling Point No. 2 Water Elevation at Time of Sampling: 21.5'

	Depth in Feet (approximate)										
Parameter	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	
Temp °C	15.92	15.90	15.90	15.90	15.90	15.90	15.89	15.86	15.86	15.25	
mS/cmC	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.424	0.425	0.426	
Ms/cm	0.352	0.352	0.352	0.352	0.352	0.352	0.352	0.350	0.351	0.351	
DO%	32.4	32.4	32.5	32.5	32.7	32.9	33.2	33.6	36.0	42.4	
DO mg/L	3.20	3.20	3.21	3.21	3.23	3.25	3.28	3.32	3.56		41.90??
DO ch	36.9	38.0	38.0	38.0	36.9	36.9	36.9	38.0	38.0	38.0	
pH	7.69	7.66	7.68	7.68	7.69	7.69	7.76	7.67	7.68	7.68	
pHmV	-47.3	-45.4	-46.4	-46.9	-47.0	-47.0	-46.1	-46.0	-46.5	-46.7	
ORP	512.4	508.3	499.3	484.7	485.4	478.2	454.2	435.6	435.4	432.3	

Hessian Hills Tank Water Elevation at Time of Sampling: 10.7'

	Depth in Feet (approximate)				
Parameter	**0**	**6**	**8**	**10**	**12**
Temp °C	15.84	15.84	15.84	15.84	15.81
mS/cmC	0.430	0.429	0.429	0.428	0.429
Ms/cm	0.354	0.354	0.354	0.354	0.364
DO%	41.2	41.2	41.3	41.9	44.1
DO mg/L	4.07	4.08	4.09	4.18	4.37
DO ch	41.0	42.0	42.0	41.0	41.0
pH	7.75	7.76	7.76	7.77	7.77
pHmV	-50.4	-50.6	-50.8	-51.4	-51.2
ORP	374.7	376.0	377.0	376.7	364.4


North Highlands Tank
Sampling Point: #1
Sampling Date: 11/03/05
Temp (° C)
DO (mg/L)
pH
ORP
See Legend
ORP
Depth (ft)
0
5
10
15
20
25
300
370
440
510
580
650



North Highlands Tank
Sampling Point: #2
Sampling Date: 11/03/05
Temp (° C)
DO (mg/L)
pH
ORP
See Legend
ORP
Depth (ft)
0
5
10
15
20
25
300
370
440
510
580
650

Appendix B:
General Plan of Highland Tank Site