# TUNNEL DRAIN COLLECTION SYSTEM PERFORMANCE EVALUATION AND PHASE THREE COMPLETION REPORT GENERAL ELECTRIC HUDSON FALLS PLANT SITE

HUDSON FALLS, NEW YORK

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# EXECUTIVE SUMMARY

The Hudson Falls Tunnel Drain Collection System (TDCS) became fully operational in May 2009. This TDCS performance monitoring and construction completion report serves two purposes. First, it provides an evaluation of the performance of the completed TDCS as it relates to groundwater remedy goals for the Site, and second, it provides documentation regarding completion of Phase Three of the TDCS construction. The TDCS is a substantial component of the groundwater portion of the comprehensive remedy selected by the NYSDEC for the General Electric (GE) Hudson Falls Plant Site (the "Site") (NYSDEC, 2004). The remedial action objectives (RAOs) for the Site remedy (GeoTrans et al., 2001; GeoTrans, 2004), which were based on the ROD-specified Site remediation goals (NYSDEC, 2004), are to:

- Prevent or minimize PCB releases to the Hudson River;
- Prevent or minimize migration of contaminated groundwater from the Site;
- Prevent or minimize direct contact with contaminated soil and shallow groundwater; and
- Prevent exposure to contaminated groundwater east of the Site.

The TDCS, which is an unprecedented under-the-river groundwater collection system, was designed to address the first two listed RAOs. The TDCS consists of a 200-foot deep 24-foot diameter shaft, three 10-foot diameter tunnel segments with a combined length of approximately 1000 feet, and 20 drain wells drilled from the tunnel segments upward through the Snake Hill Shale formation. The TDCS is a significant enhancement to the operating interim remedial measure (IRM) for groundwater, which is a groundwater and dense non-aqueous phase liquid (DNAPL) recovery system consisting of 35 discrete extraction or recovery locations. The TDCS was designed and constructed to expand the existing hydraulic capture zone to extend beyond the known extent of PCB-containing NAPL in the bedrock beneath Bakers Falls and the Hudson River, to create downward hydraulic gradients from the Hudson River toward the TDCS in the vicinity of the Site, and to create or increase upward hydraulic gradients from the Glens Fall Limestone toward the Lower Snake Hill Shale and the TDCS. In addition to meeting the

RAO's for the Site, the expanded hydraulic capture zone and creation of downward hydraulic gradients from the Hudson River to the TDCS were expected to provide the additional source control for the Site needed to achieve EPA's proposed water column PCB target at Rogers Island; a value of 2 ng/L was assumed in models used for the Hudson River PCB Site Reassessment RI/FS to be the upstream target concentration at Rogers Island in response to source controls at the GE Hudson Falls Plant.

Hydraulic gradients, calculated from water level measurements, provide evidence that the expected additional source control for the Site has been achieved. Comparison of Hudson River water column PCB concentrations in samples collected in 2010 at the Boat Launch located adjacent to the Site, and at Roger's Island located approximately three miles downstream from the Site, to the historical record of PCB concentrations at those sampling locations provides evidence that the TDCS has achieved the anticipated additional source control for the Site.

TDCS construction began in September 2007. The TDCS became fully-operational from a hydraulic effectiveness perspective in May 2009, when the 20 drain wells were completed and opened. Operating the drain wells has a significant hydraulic effect because the installation of the drain wells created many near-vertical interconnections among the Upper, Middle and Lower Snake Hill Shale units along the length of the three TDCS tunnel segments.

Monitoring for purposes of evaluating the performance of the TDCS began in 2005 and continued throughout the TDCS construction and operation. Several reports which summarized the hydraulic effects observed during TDCS construction, and one report which recommended a realignment of the TDCS to address concerns raised by NYSDEC regarding the effects of tunnel blasting, were prepared and submitted to the NYSDEC (GeoTrans, 2008a; GeoTrans, 2008b; GeoTrans, 2009; GeoTrans, 2010) during the period of TDCS construction. This report focuses primarily on data collection and evaluations made during full-scale TDCS operation, from May 2009 through March 2011.

Specific data collection activities that were implemented for the purpose of providing information to be used to evaluate the effectiveness of the TDCS at achieving the RAOs for the Site groundwater remedy and providing additional source control for the Site included:

- Hydraulic monitoring, including:
    - groundwater flow rates of the TDCS and individual on-Site recovery wells,
    - Hudson River stage, and
    - groundwater levels.
- DNAPL collection and DNAPL recovery rate monitoring;
- Hudson River water column PCB concentration monitoring;
- Monitoring Site-wide groundwater quality for PCB and VOC concentrations.

Hydraulic monitoring has provided the data necessary to document the changes in the rate of groundwater extraction from the Site, as well as the extent of the TDCS hydraulic capture zone. Recovery well and TDCS groundwater extraction rate data provide evidence that operation of the TDCS has resulted in an almost 50 percent increase in the amount of groundwater extracted from beneath the Site, and an approximately 30 percent reduction in the rate of groundwater extraction by the IRM recovery wells. The total average rate of groundwater extraction from beneath the Site has increased from approximately 65 gallons per minute (gpm) for the two-year period prior to TDCS construction to an average rate of approximately 96 gpm during 2010. This is an approximately 50 percent increase in the total groundwater extraction rate from the Site. The average rate of groundwater extracted in 2010 by the TDCS was 53 gpm, and the average rate of groundwater extraction in 2010 by the IRM recovery wells was 43 gpm. The average rate of groundwater extraction by the IRM recovery wells in 2010 was 22 gpm less than during the two-year period prior to the start of construction of the TDCS. The reduction in the groundwater extraction rate by the IRM wells was caused by diversion of groundwater away from the recovery wells and to the TDCS. Flow rates from individual TDCS drain wells ranged from less than 0.1 gpm to 8.3 gpm during 2010.

Water level data that have been collected provide evidence that the TDCS has created a much larger hydraulic capture zone than was created solely by the IRM recovery wells. The Hudson River stage data and groundwater potentiometric data were used to prepare Site-wide potentiometric maps and potentiometric sections of the Overburden, the Upper, Middle, and Lower Snake Hill Shale units, and the Glens Falls Limestone as well as hydrographs of individual water level monitoring locations. The potentiometric maps, potentiometric sections and hydrographs were then used to estimate the hydraulic capture zone of the Site groundwater remedy.

The water level data combined with groundwater quality data also provide evidence that the TDCS hydraulic capture zone extends beyond the known extent of DNAPL beneath the Hudson River. Water level data from some of the monitoring wells, screened in lower hydraulic conductivity zones of the Snake Hill Shale, also provide evidence that the hydraulic effect of TDCS operation has not yet stabilized and that the hydraulic zone of influence, and therefore the zone of capture, of the Site groundwater remedy are still expanding.

DNAPL collection and DNAPL recovery rate data indicate that there has not been significant mobilization of DNAPL as a result of TDCS construction and operation. Observations regarding DNAPL collection and recovery made during the TDCS construction and the approximately 18-month operational period indicate that there have been small-scale spatial and temporal variations in DNAPL collection rates. DNAPL is known to be seeping into and collected by the TDCS, but the rate of seepage is low and sporadic. Quantification of the total DNAPL seepage into the TDCS has not yet been possible due to the sporadic nature and small volumes of DNAPL seepage that have occurred at a few discrete locations. Small-scale seepage has been observed during the periodic tunnel entries, and PCB concentrations in TDCS discharge samples exceed PCB solubility limits in water, thereby indicating DNAPL presence in the water pumped from the TDCS. The Site-wide DNAPL recovery rate has continued to decline during the TDCS construction and operation phases. The average Site-wide DNAPL collection rate during the baseline monitoring period of 2005 and 2006 was 938 liters per year. In 2010, the annual Site-wide DNAPL collection rate was 560 liters per year.

Hudson River PCB concentration data collected at the Boat Launch sampling station adjacent to the Site and at the downstream Rogers Island station provide evidence that within a few months after full-scale TDCS operation began, there was a noticeable and continual reduction in both total and tri+ PCB concentrations in river water column samples. In addition, PCB concentrations in Hudson River samples collected in 2010 at a sampling location upstream of the Fort Edward Plant Former 004 Outfall, which is located downstream of the Site, were all less than the detection limit. The observed PCB concentrations at these three Hudson River water column monitoring stations provides additional evidence that the TDCS is meeting the groundwater RAOs for the Site and is providing additional source control for the Site.

Groundwater quality sampling for PCB and VOC analysis of 97 monitoring wells at the Site and adjacent GL&V property, as well as the TDCS drain wells has confirmed that the TDCS is located within the central portion of the region of contaminated groundwater at the Site, and that the TDCS tunnel segment 3 extends beyond the known extent of DNAPL in the bedrock beneath the river.

Another principal component of the Site remedy was the expansion of the existing water treatment plant (WTP). Regional groundwater flow model analyses performed prior to TDCS construction indicated that the flow rate to the Site WTP could exceed 150 gpm from all sources. In order to treat the increased water flow estimated to result from TDCS construction and operation, the total capacity of the on-Site WTP was increased to 375 gpm. Eighteen months of water treatment plant operational data continue to confirm that the increased groundwater extraction rate and any associated water quality changes that resulted from construction of the TDCS are well within the capacity of the on-Site WTP.

In addition to collecting monitoring data to evaluate the effectiveness of the TDCS, other construction and operational monitoring activities occurred between May 2009 and December 2010. These additional activities included:

- installation of new monitoring wells, including the conversion of two large-diameter former extraction wells into multi-level monitoring wells, to provide a more extensive groundwater monitoring network for evaluating TDCS effectiveness;
- periodic inspections of the exposed tunnel walls and ceiling for the purposes of evaluating tunnel stability and safety; and

- replacement of the temporary TDCS sump pumps with permanent pumps and other key pump and discharge line components, including a fiber optic communication link between the TDCS and the WTP, which made reliable full-scale operation of the TDCS possible.

Several recommendations regarding the operation, maintenance and monitoring of the TDCS are made in this report. The recommendations, which are described in more detail in Chapter 7, are:

- Optimize the operation of the Site groundwater remedy by shutting down inefficient and unnecessary recovery wells, and redeveloping other more effective wells.
- Develop a Long-Term Monitoring Plan for the Site to provide periodic documentation of the performance and effectiveness of the Site groundwater remedy.
- Re-evaluate and revise the scope of Phase Four TDCS construction to be aligned with requirements of the expected biannual frequency of TDCS entries.
- Continue the ongoing operation and maintenance of the TDCS in its current configuration and perform periodic inspections of the TDCS during biannual entries to perform equipment maintenance.

In summary, the monitoring data collected during the first 18 months of TDCS operation provide evidence that the RAOs for the Site groundwater remedy have been achieved and that the TDCS has provided the additional source control that was intended. There is no indication that additional enhancements to the TDCS are necessary at this time to continue to meet the remedy design goals.

# 1 INTRODUCTION

This report presents an evaluation of the performance of the Hudson Falls Tunnel Drain Collection System (TDCS) based on hydraulic and water quality monitoring data collected prior to, during, and subsequent to completion of Phase Three construction. This report also presents the Phase Three TDCS construction completion and details of the first 18 months of full-scale operation & maintenance.

## 1.1 BACKGROUND

Phase Three was the last of three phases of TDCS construction that included: Phase One – shaft construction; Phase Two - tunnel excavation and; Phase Three - piezometer and drain well installation. The constructed TDCS consists of a 200 foot deep 24-foot diameter shaft, three 10-foot diameter tunnel segments with a combined length of approximately 1000 feet, and 20 drain wells drilled from the tunnel segments upward through the Snake Hill Shale formation. The layout of the constructed TDCS is shown on Figure 1-1.The layout of the constructed TDCS is different than the originally approved design. In response to concerns raised by the NYSDEC during the Phase One construction regarding the proximity of one of the planned tunnel segments to the Bakers Falls dam GE evaluated alternate tunnel alignments that would provide a greater distance between the tunnels and the Bakers Falls dam. The evaluation and a proposed alternative tunnel alignment was submitted to NYSDEC on May 19, 2008, (GeoTrans, 2008) and approved by NYSDEC June 9, 2008.

TDCS construction began in September 2007, and the TDCS became fully-operational from a hydraulic effectiveness perspective in May 2009, when the 20 drain wells were completed and opened. Opening of the drain wells had a significant hydraulic effect because it created many near-vertical interconnections among the Upper, Middle and Lower Snake Hill Shale units along the length of the three TDCS tunnel segments. Monitoring data that were evaluated for this report were collected between September 2005 and November 2010. The report includes an assessment of the TDCS performance over the first 18 months of full-scale operation.

Groundwater monitoring was done in accordance with the GE Hudson Falls Plant Site Groundwater Remedy Tunnel/Drain Collection System Construction Phase

Monitoring Plan (GeoTrans, 2006) which was included as Attachment 5D in the NYSDEC-approved Bid and Construction Documents For Hudson Falls Tunnel Drain Collection System (Tetra Tech, 2006). The purpose of the monitoring was to document the hydraulic effects of TDCS construction and operation, including the groundwater flow rate to the TDCS, the hydraulic capture zone of the TDCS, and the effect of the TDCS on groundwater and DNAPL recovery rates from existing on-Site wells in order to evaluate the ability of the TDCS to achieve the remedial action objectives (RAOs) for groundwater at the Site.

Three separate hydraulic monitoring reports which corresponded to the separate phases of TDCS construction were submitted to NYSDEC (GeoTrans, 2008a, 2009, and 2010). The Phase One Report (GeoTrans, 2008a) documented the hydraulic effects of shaft construction. Construction dewatering during shaft excavation caused water levels in the Snake Hill Shale near the shaft to decline. The dewatering also caused the RW-100 and RW-104 groundwater pumping rates to decline. The DNAPL recovery rate from monitoring well HF-108, which is located near the shaft, increased during this phase of construction. The increase in DNAPL recovery rate from well HF-108 was interpreted to have been caused by the hydraulic head changes near the shaft. The Phase One Report also described modifications made to the regional groundwater flow model based on data collected and observations made during the shaft construction, and presented a comparison of observed and model-calculated water levels. The Phase One Report concluded that the observed hydraulic responses were similar to the model-calculated responses and that the model would be a useful tool for both anticipating and evaluating the hydraulic effects of TDCS construction.

The Phase Two Report (GeoTrans, 2009) documented the hydraulic response to construction of the three tunnel segments. The location and orientation of the three tunnel segments are shown on Figure 1-1. Dewatering during the tunnel construction caused further decline of the Snake Hill Shale and Glens Falls Limestone water levels. Short-term increases and decreases of DNAPL recovery rates from some recovery and monitoring wells was observed. The increased groundwater discharge from the TDCS resulted in additional decreases in pumping rates from recovery wells RW-100 and RW-104 located near the TDCS. The Phase Two Report also described modifications made to the regional groundwater flow model based on observations made during the shaft and tunnel construction, and presented a comparison of observed and model-calculated water levels. A comparison of the observed water levels and groundwater flow rate to the TDCS to model-calculated water levels and flow rates indicated that the groundwater flow model provided an adequate representation of hydrogeologic conditions and that the model would continue to be a useful tool for evaluating the hydraulic effects of construction of the TDCS.

The Phase Three Report (GeoTrans, 2010) documented the Phase Three construction activities and the hydraulic response to the first six months of full-scale TDCS operation. The operation of the drain wells, which extended upward from the tunnel segments and created vertical connections within the Snake Hill Shale caused substantial additional water level decline in the Snake Hill Shale, but there was little additional drawdown in the underlying Glens Falls Limestone. The Phase Three Report recommended additional actions be taken to better monitor the performance of the TDCS. These additional actions included:

- Conversion of probe hole PH-2 to a multi-level piezometer;
- Installation of a Lower Snake Hill Shale monitoring well at the V-14BD, V-214 well cluster;
- Collection and analysis of water samples from the TDCS drain wells; and
- Performing a Site-wide groundwater sampling round.

In addition, as recommended in the Bedrock Remedial Investigation and Feasibility Study Report (GeoTrans, 2001). GE converted the two former GL&V production wells (PW-1 and PW-2) to multi-level monitoring well clusters to better monitor water quality and water levels south of the TDCS.

### 1.2 REPORT OBJECTIVES

This report presents the monitoring data collected during the first 18 months of full-scale TDCS operation, an evaluation of the performance of the Hudson Falls bedrock groundwater remedy, including the TDCS, and a summary of the completion of Phase Three TDCS construction.

The monitoring data that were evaluated included the following elements:

- Automated water level monitoring in 48 wells and piezometers using pressure transducers and data loggers;
- Periodic manual water level measurements in 253 wells;
- Extraction rate monitoring from recovery wells, TDCS drain wells, and the TDCS;
- DNAPL recovery rate measurements from recovery and monitoring wells;
- Hudson River stage measurements at two locations;
- Hudson River water column PCB concentration monitoring;
- Periodic DNAPL monitoring in 111 wells; and
- Site-wide groundwater sampling.

The location of the TDCS and other Site features and monitoring locations are shown in Figure 1-1.

Also included in this report are:

- Final construction details of the piezometers, drain wells, and probe holes;
- Descriptions of the pumping station construction and startup;
- A description of multilevel piezometer PZ-202 installation in TDCS Tunnel Segment 2;
- A description of monitoring well V-114 installation;
- A description of the conversion of former GL&V extraction wells PW-1 and PW-2 to monitoring well clusters;
- A description of TDCS operation, monitoring and maintenance (OM&M) activities; and
- Record Drawings for TDCS construction Phases One, Two, and Three.

Throughout the TDCS construction and OM&M, monitoring data have been reported to NYSDEC in the weekly or biweekly and monthly status reports. This report presents an evaluation of the monitoring data and includes graphical presentation of the data in the form of hydrographs, potentiometric maps and sections, and DNAPL and groundwater recovery graphs.

## 1.3 REPORT ORGANIZATION

This report contains an Executive Summary, 8 Chapters and 15 Appendices. Chapter 1 is the Introduction and provides some background information. Chapter 2 summarizes the discrete hydraulic monitoring tasks that were done during the past 18 months of TDCS operation. Chapter 3 provides an evaluation of the hydraulic performance of the TDCS as it relates to meeting the remedial action objectives for groundwater. Chapter 4 describes the various TDCS-construction and well installation activities have been completed since May 2009. Chapter 5 describes the various TDCS operation, maintenance and monitoring activities that occurred since May 2009. Chapter 6 summarizes general observations and conclusions regarding the hydraulic effectiveness and operation of the TDCS. Chapter 7 provides recommendations for optimization of the Site groundwater remedy, as well as monitoring and operation and maintenance of the remedy. Chapter 8 lists the references cited in this report.

# 2 TDCS PERFORMANCE MONITORING DATA COLLECTION

Construction of the TDCS shaft began on September 18, 2007. The tunnel excavation began on March 21, 2008, and was completed on September 26, 2008. Drilling of the piezometers and drain wells began on February 7, 2009, and was completed by May 11, 2009. For purposes of this report the time interval between September 2005 and September 2007 is considered to be the TDCS pre-construction period. The time interval between September 2007 and April 2009 is considered to be the TDCS construction period, and the time period between May 2009 and December 2010 is considered to be the TDCS post-construction period (the "Operational Period").

To monitor the effects of the constructed TDCS operation on groundwater levels and groundwater flow, river stage elevations were measured at two surface water monitoring locations on the Hudson River and groundwater elevations were measured at more than 253 groundwater monitoring locations. One Hudson River monitoring location was located upstream of the Bakers Falls dam (R-1), and the other Hudson River monitoring location was in the plunge pool below the dam (R-4). River stage data were collected with pressure transducers connected to data loggers. The locations of monitoring stations R-1 and R-4 are shown on Figure 2-1.

## 2.1 HYDRAULIC MONITORING

### 2.1.1 GROUNDWATER RECOVERY RATE MONITORING

Flow rates from on-Site extraction wells, the combined TDCS discharge, individual TDCS drain wells, and the influent rate to the on-Site water treatment plant (WTP) were measured periodically during the TDCS Operational Period. The reported flow rate data were calculated from data collected by totalizing flow meters, or in the case of the TDCS drain wells, short-term flow rate measurement events. Graphical or tabular summaries of flow rate data for selected wells, the combined TDCS discharge and the influent rate to the WTP for the period May 2009 through December 2010 are included in Appendix A.

### 2.1.2 HUDSON RIVER STAGE

River stage measurements were recorded hourly at two locations, R-1 and R-4. R-1 is located upstream of the Bakers Falls Dam and records the elevation of the pool above the dam. R-4 is located in the plunge pool at the base of Bakers Falls and records the elevation of the plunge pool. The measurements are collected using pressure transducers and data loggers. Manual measurements are collected weekly as a check on the automated measurements. Graphs of Hudson River stage data are included in Appendix B

#### 2.1.3 Water Level Monitoring

During the TDCS Operational Period manual water level measurements were made on a weekly basis in 102 recovery and monitoring wells. In addition, hourly water level measurements at 48 wells were made and recorded using pressure transducers and data loggers. The locations of the monitoring wells are shown on Figure 2-1, Operational Period water level measurement frequency as well as the elevation and stratigraphic horizon of the open interval of each monitoring well is provided in Table 2-1.

Data collected between September 17, 2005 and September 17, 2007, pre-date TDCS construction. They are the baseline condition to which TDCS Operational Period data have been compared. Hydrographs of the Hudson River stage and groundwater elevation data for the period September 1, 2005 through December 31, 2010 are included in Appendix B. A graph of precipitation data for the same time period is also included in Appendix B.

### 2.2 DNAPL Recovery Monitoring

DNAPL recovery monitoring has been done in selected DNAPL recovery and monitoring wells. The frequency of DNAPL monitoring varies from weekly to annually depending on the historic DNAPL recovery rate from a well. Some of the recovery wells are equipped with DNAPL pumps at the bottom of the well. DNAPL in those recovery wells was pumped to a container located at the well head where it was collected and measured weekly. For wells without separate DNAPL pumps, DNAPL collection was done using a bailer. The bailer was lowered to the bottom of the well and any accumulated DNAPL was removed from the well, the amount of DNAPL removed was recorded, and the collected DNAPL was managed with the rest of the DNAPL collected at the Site.

Figure 2-2 shows the DNAPL recovery monitoring locations and indicates the frequency of DNAPL recovery. Table 2-2 summarizes the DNAPL recovery rates for locations that were monitored on a weekly basis. Graphs of cumulative DNAPL recovery and recovery rate trend lines for the period September 2005 through December 2010 are included in Appendix C.

## 2.3 WATER QUALITY

### 2.3.1 HUDSON RIVER

Surface water samples are collected from the Hudson River at locations upstream and downstream of the Site to fulfill requirements of various monitoring programs related to the Hudson River remedy. Upstream samples are collected monthly at the Bakers Falls station and downstream samples are collected weekly at the Rogers Island station. Samples have been collected since 1991 in accordance with the Post-Construction Remnant Deposit Monitoring Program (PCRDMP). From June 2004 through May 2009, the PCRDMP was included in the Hudson River Baseline Monitoring Program (BMP). In May 2009, GE began the Remedial Action Monitoring Program (RAMP) for the Hudson River dredging and the PCRDMP sample collection was incorporated into this program. Since 1996, GE has collected water column samples at the Site from the base of Bakers Falls near the Tailrace Tunnel (Boat Launch sample) approximately weekly. The collection of this sample is not required by the Consent Orders for the Site. In addition, in 2010 GE began collecting a grab sample from the Hudson River downstream of the Hudson Falls Site and upstream of the Fort Edward Plant Former 004 Outfall (sample location 004_HR_N). The sample locations are shown on Figure 2-3.

Collection procedures for the Bakers Falls and Rogers Island samples are described in the BMP Quality Assurance Project Plan (QAPP; QEA and ESI 2004) and the Phase 1 Remedial Action Monitoring QAPP (Anchor QEA et al., 2009). The Boat Launch sample is collected using a dedicated submersible pump and tubing connected to dedicated PVC pipe extending approximately five feet below the water surface. The sample from north of the Fort Edward Plant Former 004 Outfall is a surface grab sample collected by attaching the sample container to a length of PVC pipe. The PCB method detection limit for the Bakers Falls and Rogers Island samples was reduced to approximately 1.1 ng/L in 2004. The detection limit for the Boat Launch sample is 11 ng/L and less than 10 ng/L for the Fort Edward Plant Former 004 Outfall samples.

### 2.3.2 Groundwater Sampling

During the TDCS Operational Period, groundwater samples were collected from monitoring wells, the TDCS drain wells, the TDCS sump and the TDCS discharge. Between May and October 2010, groundwater samples were collected from 97 monitoring wells located at the Site and the adjacent GL&V property using low-flow sampling procedures (EPA, 2010). These 97 wells include previously existing monitoring wells, a newly-installed monitoring well (V-114) and multi-level monitoring well clusters installed in the former production wells (PW-1 and PW-2) on the GL&V property. Table 2-3 lists the sampling locations from which groundwater samples have been collected during the TDCS Operational Period. The following water quality parameters were monitored during sampling: pH, specific conductance, temperature, oxidation-reduction potential, dissolved oxygen content, and turbidity. The samples were sent to NEA for PCB and VOC analyses.

Twenty drain wells were installed in the TDCS between March and May, 2009. The rate of groundwater flow from each of the drain wells varies, and some do not always yield sufficient water for sampling. Water samples were collected from drain wells which had sufficient water flow to allow sampling during the tunnel entry dates of November 2, 2009, February 23, 2010, and September 16, 2010. The drain wells that were sampled flowed continuously, and samples were collected by filling sample vials directly from the drain wells without additional purging. The samples were analyzed for PCBs and VOCs.

Between March and November 2010 eight samples of TDCS discharge were collected for analysis. One sample was collected directly from the TDCS sump on March 26, 2010 during a tunnel entry to respond to a pump failure. The collected sample was sent to NEA for pH, TAL metals, chloride, sulfide, alkalinity (total), alkalinity ($HCO_3$), alkalinity ($CO_2$), sulfate, phosphate, iron, and PCB analysis. In May 2010 a sample port was installed in the TDCS discharge pipe to the WTP. The sampling port allows TDCS discharge water to be sampled without a tunnel entry. TDCS discharge samples have been collected on a monthly basis since May 2010. The samples are sent to Pace Analytical Services for PCB and VOC analysis. Groundwater sampling data are presented in Section 3.3.2 of this report.

# 3 TDCS PERFORMANCE EVALUATION

The TDCS was constructed to supplement and increase the effectiveness of an existing groundwater extraction system to meet two principal remediation goals for Site groundwater. These goals were to prevent or minimize:

- PCB migration to the adjacent Hudson River, and
- Migration of contaminated groundwater from the Site.

One of the principal performance criteria for the TDCS was to create an areally-extensive hydraulic capture zone that would extend beyond the known limits of PCB-containing DNAPL. The objective was to extend the large capture zone to further reduce the discharge of PCBs to the Hudson River. Groundwater elevation data were used to evaluate the changes in the potentiometric levels, and consequently the changes in groundwater flow directions and hydraulic capture zone caused by operation of the TDCS. Other data used to evaluate the performance of the TDCS include groundwater recovery rates, DNAPL recovery rates, and groundwater quality. The following sections summarize the evaluation of these monitoring data as it relates to the first 18 months of operation of the TDCS.

## 3.1 HYDRAULIC MONITORING

Pumping rates from individual recovery wells and the TDCS, river stage and groundwater level measurements were collected to evaluate the hydraulic performance of the TDCS.

### 3.1.1 GROUNDWATER RECOVERY RATES

Groundwater recovery includes groundwater recovery by Site extraction wells and collection sumps, the TDCS drain wells and direct inflow to the TDCS tunnel and shaft. Current flow rate monitoring allows for relatively frequent measurements of only extraction well recovery rates and the total TDCS discharge. The total TDCS discharge is a combined discharge of groundwater flow to the TDCS drain wells and direct inflow to the TDCS tunnel and shaft. Prior to TDCS construction the long-term total Site-wide average groundwater recovery rate, which was solely from the Site extraction wells and collection sumps, was approximately 65 gpm. As a result of TDCS construction, the

Site-wide average groundwater recovery rate for the year 2010 was 96 gpm, with approximately 53 gpm from the TDCS and approximately 43 gpm from the Site extraction wells and collection sumps. The net groundwater recovery rate in 2010 was 31 gpm or 48 percent greater than the average groundwater recovery rate during the baseline monitoring period prior to TDCS construction. The increased groundwater recovery rate is an indirect indication that the hydraulic capture zone of the Site groundwater remedy has increased as a result of the TDCS operation. The increased groundwater recovery is due to the expansion of the boundaries of the hydraulic capture zone, capture of groundwater that previously discharged to the Hudson River, as well as the creation of downward hydraulic gradients from the Hudson River to the Snake Hill Shale causing induced infiltration of Hudson River water to the Snake Hill Shale and subsequent capture by the TDCS.

The net groundwater flow rate extracted by the Site recovery wells and collection sumps decreased by about 22 gpm as a result of the operation of the TDCS. In general, however, with the exception of recovery well RW-100, the impact of TDCS operation on groundwater recovery rates of individual wells, has not been quantifiable. With respect to recovery well RW-100, there was an almost instantaneous effect on the groundwater recovery rate associated with the completion of the TDCS drain wells. When the drain wells were opened, the water level in RW-100 declined to the low-level pump control, and RW-100 stopped pumping. To allow continued groundwater recovery from RW-100, the low-level pump control was lowered approximately 14 feet. The average pumping rate in 2010 from the reconfigured RW100 was approximately 2.5 gpm. Compared with the pre-construction average flow rate of 6 gpm, this is a 3.5 gpm reduction.

### 3.1.2 River Stage

River stage data were used in preparation of potentiometric maps and sections and to assist in the interpretation of monitoring well and piezometers hydrographs. River stage hydrographs for the period September 2005 to March 2011 are included in Appendix B.

### 3.1.3 Groundwater Potentiometric Levels

Groundwater level monitoring has been done on a regular basis at more than 253 monitoring locations since prior to TDCS construction. Periodically, the data have been used to prepare potentiometric maps of the overburden, Snake Hill Shale, and Glens Falls Limestone and to evaluate temporal changes in water levels at individual wells. Potentiometric maps of the overburden, Upper, Middle and Lower Snake Hill Shale and the Glens Falls Limestone and an evaluation of temporal water level changes at individual wells have been presented in reports submitted at the completion of the various phases of TDCS construction (GeoTrans, 2008a; GeoTrans, 2009; GeoTrans, 2010).

Appendix B contains water level hydrographs for the period September 2005 through December 2010. The hydrographs illustrate the water level elevation variability during the pre-TDCS construction baseline period, as well as the temporal response of groundwater levels to the TDCS construction and operation. Water levels in some wells, such as HF-138, responded immediately to the opening of the TDCS drain wells and equilibrated quickly to the new hydraulic stress. Water levels in other wells, such as HF-146 and V-169, have responded more slowly, and 18 months after Phase Three of TDCS construction was completed the water levels in these wells continues to decline, apparently in response to TDCS operation (See hydrographs in Appendix B).

Figures 3-1 through 3-7 are potentiometric maps and sections that were prepared using groundwater elevation data collected on November 16, 2010. These maps represent a snapshot of the groundwater elevations at the Site after approximately 18 months of TDCS operation. Figure 3-1 represents the overburden, or unconsolidated deposits. Figures 3-2, 3-3, and 3-4 represent the Upper, Middle and Lower Snake Hill Shale, respectively. Figure 3-5 represents the Glens Falls Limestone, and Figures 3-6 and 3-7 are potentiometric sections in the vicinity of the TDCS. The lines of section are shown on Figures 3-2 through 3-5.

Figure 3-1 shows the water table elevation in the overburden. Horizontal hydraulic gradients, and therefore the lateral direction of groundwater flow in the overburden, do not appear to have been significantly changed by the TDCS operation. Groundwater flow in the overburden beneath the Site is northwesterly toward the Hudson

River and predominantly downward to the underlying bedrock. The large downward head difference between the overburden and the bedrock is illustrated on Section B-B[1] (Figure 3-6). In a large area between Sumpter Street and the Hudson River, the water table is below the top of rock and the overburden is dry. The water table is also below the top of rock and the overburden is dry beneath a portion of the area under Building 1.

The Upper Snake Hill Shale potentiometric map, Figure 3-2, shows the influence of the TDCS and the Site recovery wells on the potentiometric levels in the Upper Snake Hill Shale. There are localized potentiometric surface depressions around the extraction wells and the TDCS shaft. The TDCS shaft extends to the Lower Snake Hill Shale and has a water level elevation of about 23 feet NGVD. The potentiometric sections (Figures 3-6 and 3-7) illustrate a large downward head difference from the Upper Snake Hill Shale toward the lower portions of the shale. Water level elevations in some of the Upper Snake Hill Shale wells located along the river upstream of the dam were lower than the river stage above Bakers Falls dam, indicating that water from the river upstream of the dam flows into the shale beneath the Site.

The Middle Snake Hill Shale potentiometric map (Figure 3-3) also shows the impact of the TDCS and Site recovery wells on potentiometric levels. As there is greater number of Middle Snake Hill Shale monitoring wells near the TDCS than Upper Snake Hill Shale wells, the hydraulic effect of the TDCS on Middle Snake Hill Shale potentiometric levels is more evident than for the Upper Snake Hill Shale. Comparison of Figure 3-3 to a June 2007 Middle Snake Hill Shale potentiometric map (GeoTrans, 2008, Figure 3-4) illustrates the change in Middle Snake Hill Shale potentiometric levels and localized groundwater flow caused by operation of the TDCS. In particular, the influence of the shaft and Tunnel Segment 1 on groundwater flow directions is shown on Figure 3-3. The potentiometric sections (Figures 3-6 and 3-7) illustrate downward head differences from the Middle to the Lower Snake Hill Shale. Based on the water level data illustrated on the potentiometric maps and sections, it appears that all of the Middle Snake Hill Shale beneath the Site is within the capture zone of the TDCS and Site recovery wells.

The Lower Snake Hill Shale potentiometric map (Figure 3-4) shows a relatively large geographic area within which groundwater flow in the Lower Snake Hill Shale beneath the Site and beneath the Hudson River and Bakers Falls converges toward the TDCS. The bottom of the shaft is located in the Lower Snake Hill Shale, and the entire length of TDCS tunnel, which is dewatered and operated as a dry tunnel, is located within the Lower Snake Hill Shale. In addition, the twenty TDCS drain wells penetrate the full thickness of the Lower Snake Hill Shale above the tunnel. Comparison of Figure 3-4 to a June 2007 Lower Snake Hill Shale potentiometric map (GeoTrans, 2008, Figure 3-5) illustrates the change in Lower Snake Hill Shale potentiometric levels and localized groundwater flow caused by operation of the TDCS. The potentiometric sections (Figures 3-6 and 3-7) show that there is a downward head difference from the Middle to the Lower Snake Hill Shale and an upward head difference from the underlying Glens Falls Limestone to the Lower Snake Hill Shale. The potentiometric maps and sections indicate that the hydraulic capture zone in the Lower Snake Hill Shale extends from south of the TDCS toward the northeast at least to Bridge Street. The estimated lateral extent of the hydraulic capture zone in the Lower Snake Hill Shale is shown on Figure 3-4. The hydraulic capture zone extends beneath the plunge pool and Bakers Falls. Based on the measurements of the recently completed multi-level monitoring well clusters PW-1, PW-2, and Lower Snake Hill Shale monitoring well V-114 it appears that the southerly boundary of the capture zone is south of V-114 and the PW-2 well cluster and north of the PW-1 well cluster. Prior to the construction of the TDCS, there was an upward head difference from the Snake Hill Shale to the Hudson River indicating that groundwater flow was upward from the shale to the Hudson River. Subsequent to the construction of the TDCS, the potentiometric head in the Lower Snake Hill Shale is lower than the river stage indicating downward flow from the Hudson River into the Snake Hill Shale and toward the TDCS (see Figure 3-7, Section C-C[1]).

The Glens Falls Limestone potentiometric map (Figure 3-5) shows a depression in the potentiometric surface beneath the area of the TDCS and the Hudson River, indicating convergence of groundwater flow in the Glens Fall Limestone toward the area beneath the TDCS. The potentiometric sections illustrate large upward head differences from the Glens Fall Limestone towards the TDCS. Potentiometric section B-B' (Figure

3-6) indicates that the hydraulic capture zone in the Glens Falls Limestone extends south of monitoring well cluster PW-2.

#### 3.1.4 DRAWDOWN

Drawdown in the Snake Hill Shale and Glens Falls Limestone, resulting from the operation of the TDCS was discussed in the Phase Three Hydraulic Monitoring Status Report (GeoTrans, 2010). Review of the longer-term hydrographs from the overburden wells, included in Appendix B, indicate that the drawdown in the overburden after 18 months of full-scale operation of the TDCS ranges from about one to two feet.

Drawdown in the Upper Snake Hill Shale has been as much as 25 feet in well HF-26BS. There is an area of drawdown exceeding one foot, northwest of Sumpter and Allen streets, extending from the area of the TDCS shaft northeasterly to wells HF-24BS and HF-9D and south easterly beyond wells HF-4D and HF-68BS. More extensive drawdown has been observed in the Middle Snake Hill Shale. The area of drawdown exceeding one foot in the Middle Snake Hill Shale extends from the TDCS northeasterly to HF-59BD, located in the parking lot east of Building 1, encompassing approximately the southern half of the Site. The maximum drawdown observed in the Middle Snake Hill Shale is 34 feet observed in well HF-26BD. Drawdown in the Lower Snake Hill Shale is even more extensive than in the Middle Snake Hill Shale. The area of drawdown exceeding one foot encompasses the entire Site, extends beneath the river and approximately 300 feet south of the end of tunnel segment 2. The maximum drawdown observed in the Lower Snake Hill Shale was 98 feet in well HF-110. The open interval of well HF-110 is very close to Workroom 1-1 at the intersection of the three tunnel segments. The area of drawdown exceeding one foot in the Glens Falls Limestone extends beyond the GE property boundaries in all directions. Drawdown in the northernmost Glens Falls Limestone monitoring well HF-200, located near the intersection of Bridge and Sumpter Streets was approximately 4 feet. Drawdown in the eastern most Glens Falls well, HF-205, was approximately 3 feet. South of the TDCS the drawdown in well V-214 was greater than 2 feet. The maximum drawdown observed in the Glens Falls Limestone was 21 feet in HF-238 located near tunnel segment 1 (GeoTrans 2010).

### 3.1.5 Hydraulic Gradients in the Vicinity of the TDCS

The groundwater elevation data provide evidence that the operation of the TDCS has created a large geographic area within which hydraulic gradients are directed toward the TDCS. To further evaluate the ability of the TDCS to prevent or minimize PCB migration to the Hudson River in a DNAPL form, a more-detailed analysis of hydraulic gradients in the vicinity of the TDCS was done. It is known that the density difference between DNAPL and water creates gravitational forces that can sometimes cause DNAPL to migrate in a direction that is controlled more by the slope of geologic structures than the direction of the hydraulic gradient (GeoTrans, et al, 2001, App. B). Studies have shown, however, that if the magnitude of the hydraulic gradient exceeds the density contrast between the DNAPL and water, then the hydraulic gradient can be an effective barrier to DNAPL migration along geologic structures whose slope is different from the slope of the hydraulic gradient (GeoTrans, et al, 2001, App. B). Groundwater flow model analyses, including use of a discrete fracture network model, during the RI/FS indicated that the TDCS would likely create hydraulic gradients of sufficient magnitude to be an effective barrier to DNAPL migration to the Hudson River (GeoTrans, et al., 2001, App. B). The average measured specific gravity of the DNAPL present at the Hudson Falls Site was approximately 1.3, and ranged between 1.2 and 1.4. The average density contrast between the DNAPL and water is 0.3 and ranges between 0.2 and 0.4. Consequently, a hydraulic gradient equal to or exceeding 0.4 would be an effective barrier to DNAPL migration along any geologic structures whose direction of slope differs from the direction of the hydraulic gradient.

Six three-level piezometer clusters were installed from inside the TDCS to provide data regarding the groundwater elevations beneath the Hudson River. The water level data from these 18 piezometers that were used to prepare the November 16, 2010 potentiometric maps and sections are included in Table 3-1, which summarizes the relative direction and magnitude of hydraulic gradients in the vicinity of the TDCS. The table identifies the specific piezometer measurement locations, the distance of each from the tunnel, the groundwater elevation data for each measurement location and the hydraulic gradient between each piezometer location and the tunnel, as well as between individual piezometers within a piezometer cluster.

The hydraulic gradient data indicate that the hydraulic gradient from any single piezometer and the tunnel is toward the TDCS, the data also indicate that with two exceptions the hydraulic gradients between adjacent piezometers is also toward the TDCS. The two exceptions are the hydraulic gradient between PZ-202C and PZ-202B and PZ-303B and PZ-303A. The hydraulic gradient analysis also indicates that, with the exception of PZ-202C (gradient=0.252), PZ-202B (gradient=0.382), PZ-303C (gradient=0.394) and PZ-304 (gradient=0.392), the magnitude of the hydraulic gradient between any piezometer and the TDCS exceeds 0.4.

The November 16, 2010 water level data from the surface water station R-4 indicate that the Hudson River water level in the vicinity of the plunge pool was lower than the groundwater elevation in PZ-201C (see Figure 3-7, Section C-C[1]). This means that not only was there a hydraulic gradient from PZ-201C toward the TDCS, but there was also a hydraulic gradient from PZ-201C toward the Hudson River. PZ-201C water level data collected at other times have been lower than the Hudson River water level. These data are interpreted to indicate that in the vicinity of the Plunge Pool on the western side of the Hudson River (see Figure 3-4) shallow groundwater discharge to the Plunge Pool may occur occasionally.

## 3.2 DNAPL RECOVERY

Increases in DNAPL recovery rates were observed in a few wells, such as HF-108, HF-59BD, and RW-106 during the TDCS construction and operation. The increase in DNAPL recovery rate at HF-108 appears to have been a relatively short-term phenomenon associated with the shaft excavation. The rate of DNAPL recovery from HF-108 has continued to decline since the initial increase in DNAPL recovery rate was observed shortly after shaft construction began. The increase in DNAPL recovery rate at HF-59BD appears to have been a relatively short-term phenomenon associated with the opening of the drain wells, and the DNAPL recovery rate from this well is declining. The increase in DNAPL recovery rate at RW-106, which began during the TDCS construction phase, has continued throughout the 18 month Operational Period, but has been declining during the past two years. The current DNAPL recovery rate from RW-106 exceeds the DNAPL recovery rate observed during the baseline monitoring period of 2005 to 2007, but is less than the DNAPL recovery rate observed in the period 1999 to 2001. The observed increases in DNAPL recovery rates at some wells, however, have been offset by decreases in DNAPL recovery rates at other wells. On a Site-wide basis, the general decline in the total DNAPL recovery rate from recovery and monitoring wells that had been observed prior to the TDCS construction continued during the first 18 months of TDCS operation. The average Site-wide DNAPL collection rate during the baseline monitoring period of 2005 and 2006 was 938 liters per year. In 2010, the annual Site-wide DNAPL collection rate was 560 liters per year. Graphs of Site-wide and individual well cumulative DNAPL recovery and recovery rate trend lines for the period September 2005 through December 2010 are included in Appendix C.

During TDCS operation, the total DNAPL recovery rate from the TDCS could not be quantified due to the sporadic nature and small volumes of DNAPL seepage that have occurred at a few discrete locations. DNAPL has been observed flowing into the TDCS drainage system. The DNAPL is most frequently observed as discrete globules entrained within the groundwater flowing in the gutter drains of the TDCS walkways. Fluids in the gutter drains flow to the TDCS sump and are pumped to the on-Site WTP. The fluids pumped from the TDCS are a mixture of water, suspended solids, and DNAPL. During the first 18 months of TDCS operation, only a small amount of DNAPL settled in the DNAPL collection sump located within the TDCS. Based on the observations to date it is believed that the small amount of DNAPL being collected by the TDCS is entrained in the water pumped from the TDCS and by-passes the DNAPL collection sump, or there is only a small amount of DNAPL flowing into the TDCS. Modifications to the TDCS pumping system to improve the quantification of DNAPL collected by the TDCS are being evaluated.

The small amount of DNAPL that has flowed into the TDCS suggests that there are no large accumulations of DNAPL, in the bedrock in the vicinity of the TDCS, that are mobile under the hydraulic conditions with the TDCS operating.

## 3.3 WATER QUALITY

Water samples were collected for three general purposes:

- To evaluate the PCB concentration in the Hudson River adjacent to and downstream of the Site;

- To determine PCB and VOC concentrations in groundwater that is being captured by the TDCS; and
- To determine the current spatial distribution of PCB- and VOC-contaminated groundwater at the Site and vicinity.

The PCB concentrations in the Hudson River are measured at four locations: upstream of the Hudson Falls Dam, at the Boat Launch, adjacent to the Fort Edward Plant Former 004 Outfall, and at the Route 197 bridge at Rogers Island. The PCB and VOC concentrations in groundwater that are being captured by the TDCS are represented by the results of the TDCS sump and discharge samples as well as the drain well samples. The current spatial distribution of PCB- and VOC-contaminated groundwater at the Site is represented by the results of the monitoring well sampling, including the newly-installed well V-114, and the reconfigured GL&V supply wells PW-1 and PW-2. Each of these three categories is discussed separately.

### 3.3.1 PCB Concentrations in the Hudson River

To evaluate the effects of the construction and operation of the TDCS on PCB concentrations in the Hudson River, surface water samples were collected at four locations: upstream of the Bakers Falls Dam, at the Boat Launch, adjacent to the Fort Edward Plant Former 004 Outfall, and at the Route 197 Bridge at Rogers Island. The locations of the sampling points are illustrated on Figure 2-3. The data were grouped into three time periods: the pre-construction, construction, and operational periods. The pre-construction period is defined as September 2005 to August 2007. The construction period is defined as September 2007 to May 2009 and the operational period is from May 2009 to present. The data analyzed included total PCB and total Tri+ PCB concentrations, as well as PCB mass discharge at the Bakers Falls and Rogers Island sampling locations. Table 3-2 includes total PCB and total Tri+ PCB concentrations, daily average discharge at the Fort Edward gauging station, and PCB mass discharge for the period September 2005 through March 2011.

The analysis includes evaluation of concentration versus time graphs and trend line calculations during each period of interest to illustrate the effects of the TDCS construction and operation on PCB concentrations in the Hudson River. The graphs of

Total Tri+ PCB concentration data are annotated to highlight the concentration of 2 ng/L for visual comparison of measured concentrations to previously estimated concentrations used in Hudson River model simulations (EPA, 2002). The value of 2 ng/L was assumed in models used for the Hudson River PCB Site Reassessment RI/FS to be the upstream target concentration at Rogers Island in response to source controls at the GE Hudson Falls Plant. In addition, PCB mass discharge was calculated and graphed to include the variation in river flow rates in the evaluation of the effects of the TDCS construction and operation on surface water quality adjacent to and downgradient from the Site.

#### *3.3.1.1 Bakers Falls*

The total PCB concentrations for samples collected upstream of the Site at the Bakers Falls Dam are plotted on Figure 3-8. The figure illustrates an apparent seasonal variation in total PCB concentrations during the pre-construction and construction periods with a range from less than <0.06 to 2.9 ng/L. During the TDCS Operational Period, a seasonal variation is not as evident and the range of total PCB concentrations is less, from 1.1 to 1.9 ng/L. The total PCB concentration trend lines indicate a slight increase in concentrations during TDCS construction, however the trend in total PCB concentrations after construction was complete is downward. Figure 3-9 illustrates that total Tri+ PCB concentrations during the pre-construction and construction periods ranged from less than <0.004 to 1.6 ng/L. During the TDCS Operational Period, the range of PCB concentrations was 0.14 to 1.04 ng/L. The tri+ PCB concentration trend lines indicate a slight increase in concentrations during construction and minimal trends in total PCB concentrations before and after TDCS construction.

The mass discharge of total PCB and Total Tri+ PCB at the Bakers Falls Dam during the three periods of interest is illustrated in Figures 3-10 and 3-11. Figure 3-10 indicates an increasing trend for total PCB mass discharge during construction and a decreasing trend before and after construction. Figure 3-11 indicates an increase in total Tri+ PCB mass discharge during construction and minimal trends in total PCB concentrations before and after construction.

#### 3.3.1.2 BOAT LAUNCH

The total PCB concentrations for samples collected at the Boat Launch are plotted on Figure 3-12. Total PCB concentrations ranging from less than 7.5 to 149 ng/L were detected. The trend analysis of the data indicates an increasing trend in total PCB concentrations during the pre-construction and construction time periods and a decreasing concentration trend during the TDCS Operational Period. In addition, since December 2010, the variation in total PCB concentrations has decreased and concentrations remained less than 15 ng/L. Figure 3-13 illustrates that Total Tri+ PCB concentrations during the pre-construction and construction periods ranged from 0.37 to 137 ng/L. During the TDCS Operational Period, the range of PCB concentrations was 1.69 to 132 ng/L. The Total Tri+ PCB concentration trend lines indicate an increasing trend during pre-construction and construction time periods and a decreasing concentration trend in Total Tri+ PCB concentrations during the TDCS Operational Period.

A statistical analysis of the PCB concentrations reported for the Boat Launch was done to evaluate and compare the data from each time period. The method of analysis included tests for normality, analysis of variance, and non-parametric median analyses. The details of the tests are included in Appendix D. The results indicate that during construction, the median PCB concentration was greater than median PCB concentrations before and after construction. The median PCB concentration during the Operational Period was comparable to the pre-construction median PCB concentration. Due to the eddy currents and periodic stagnant river flow conditions in the plunge pool caused by operation of the Hudson Fall hydroelectric facility, a reliable river flow rate cannot be determined, and the Boat Launch PCB concentration data cannot be used to calculate a PCB mass discharge for this sampling station. This Boat Launch station provides qualitative estimates of change in PCB concentrations over time in the river near the Site.

#### 3.3.1.3 FORMER 004 OUTFALL UPSTREAM SAMPLING LOCATION

Weekly, when weather allows, collection of Hudson River surface water grab samples at location 004_HR_N located downstream from the Site and upstream from the Former 004 Outfall of the GE Fort Edward Plant began in June 2010. The sampling location is illustrated on Figure 2-3. These samples do not provide average PCB concentrations for the cross section of the river at which the samples were collected and therefore estimates of PCB mass discharge cannot be made from these data. However, it does provide an indication of PCB concentration change over time.

Analytical results from June to October 2010 indicate that PCBs have not been detected at a reporting limit 7.3 to 9.4 ng/L. PCB concentrations reported for samples collected at 004_HR_N are included in Table 3-1.

#### *3.3.1.4 Rogers Island*

The total PCB concentrations for samples collected downstream of the Site at Rogers Island are plotted on Figure 3-14. Total PCB concentrations range from less than <0.9 to 17.9 ng/L. Similar to the PCB concentrations at the Boat Launch, the trend analysis indicates increasing PCB concentration trends during the TDCS pre-construction and construction periods and a decreasing PCB concentration trend during the TDCS Operational Period. The Total Tri+ PCB concentration data exhibit a range of PCB concentrations from less than <0.2 to 14.9 ng/L (Figure 3-15). During the TDCS Operational Period, the range of Total Tri+ PCB concentrations is from 0.3 to 5.9 ng/L. The trend line analysis indicates an increasing trend in Total Tri+ PCB concentrations during the pre-construction and construction period. During the TDCS Operational Period, the trend in Total Tri+ PCB concentrations is downward. Since March 2010, the Total Tri+ PCB concentrations at Rogers Island have been consistently less than the Hudson River ROD target for upstream Total Tri+ PCB concentration of 2 ng/L used in the Hudson River PCB transport model

The total PCB and Total Tri+ PCB mass discharge at Rogers Island during the three periods of interest is illustrated in Figures 3-16 and 3-17. Figure 3-16 illustrates an increasing trend for total PCB mass discharge during TDCS construction and a decreasing trend after construction. Figure 3-17 also illustrates an increase in Total Tri+ PCB mass discharge during TDCS construction and a decreasing trend in concentrations after construction.

To assess the change in Total PCB mass discharge at Rogers Island in response to the construction and operation of the TDCS, the average Total PCB mass discharge at Bakers Falls and Rogers Island was calculated for each time period. The net average Total PCB discharge at Rogers Island was calculated by subtracting the average mass discharge at Bakers Falls from the average mass discharge at Rogers Island for each time period. The results indicate that the net Total PCB mass discharge at Rogers Island increased from 0.047 lb/day, during the pre-construction period, to 0.072 lb/day during the construction period. Since the TDCS has been operational, the net Total PCB mass discharge has decreased to 0.031 lb/day and since March 2010, the net Total PCB mass discharge has decreased to 0.013 lb/day. The calculations of net Total PCB mass discharge for the various time periods are summarized below.

| Location | Time Period | | | |
|---|---|---|---|---|
| | Pre-Construction | Construction | Operational | Operational since Mar 2010 |
| Bakers Falls | 0.034 | 0.038 | 0.042 | 0.036 |
| Rogers Island | 0.082 | 0.110 | 0.073 | 0.049 |
| Net* | 0.047 | 0.072 | 0.031 | 0.013 |

* Net = Rogers Island - Bakers Falls

### 3.3.2 GROUNDWATER CAPTURED BY THE TDCS

#### *3.3.2.1 TDCS SUMP AND DISCHARGE SAMPLES*

As mentioned previously a total of eight samples of TDCS discharge have been collected. One sample was collected directly from the TDCS discharge sump, and the other 7 samples were collected from the TDCS total discharge line. The analyte list for the sump sample was different from the analyte list for the TDCS discharge samples. The sump sample results are summarized in Table 3-3. The total PCB concentration of this sample was 30,500 ug/L, indicating the presence of PCB DNAPL in the sump. The general chemistry parameters and total metals concentrations were lower than similar analyses done on samples collected from nearby groundwater monitoring wells in the year 2000.

The analytical results of the seven TDCS discharge samples collected between May and November 2010 are summarized in Tables 3-4 and 3-5. Total PCB concentrations for the seven samples ranged from 92 ug/L to 513 ug/L, and the total VOC concentrations for the seven samples ranged from 96 ug/L to 326 ug/L. The PCB concentrations in several of the TDCS discharge samples were greater than the aqueous solubility limit of Aroclor 1242, indicating that PCB DNAPL was present in the TDCS discharge.

Between May and October 2010, Aroclor 1242 and Aroclor 1254 were the PCBs detected in the TDCS discharge samples. However, the November 2010 results did not detect either of these forms of PCB, but instead detected Aroclor 1248 at a concentration of 513 ug/L. The December 1, 2010 sample results indicated the presence of Aroclor 1248 at a concentration of 193 µg/L. Aroclor 1248 is not a common PCB detection for the Site and has not been detected in any of the drain well samples. However, it has been detected at a few on-site wells. Most Aroclor 1248 detections in Site groundwater samples have been less than 80 ug/L, with the highest concentration of 192 ug/L detected in a sample from well HF-77BS located north of the shaft. The most common VOCs detected were: 1,1-Dichloroethane, 1,2,3-Trichlorobenzene, 1,2,4-Trichlorobenzene, cis-1,2-Dichloroethene, Trichloroethene, and Vinyl Chloride. Cis-1,2-Dichloroethene was detected at the highest concentrations.

#### *3.3.2.2 TDCS DRAIN WELL SAMPLES*

Groundwater samples were collected from the TDCS drain wells during three separate sampling events. Not all drain wells were sampled during each of the three sampling events because the flow rate from several drain wells was too low to allow sample collection. The samples that were collected were analyzed for PCBs and VOCs. The analytical results for the drain well samples are summarized in Tables 3-6, 3-7, and 3-8. PCB concentrations for the three sampling events are shown on Figure 3-18.

In general, higher PCB and VOC concentrations are detected in Tunnel Segments 1 and 2, which are located closer to the Site, than in Tunnel Segment 3, which extends away from the Site and beneath the Hudson River. The low and non-detectable PCB concentrations reported for groundwater samples collected from the drain well at the far end of Tunnel Segment 3 (DW-307) provide evidence that Tunnel Segment 3 extends beyond the westerly extent of DNAPL in the bedrock beneath the Hudson River.

### 3.3.3 Site-Wide Groundwater Quality

Groundwater samples were collected for PCB and VOC analysis from 97 monitoring wells at the Site and the adjacent GL&V property. Many of the wells had been sampled previously in the year 2000 for PCB and VOC analysis, and 12 recently installed wells were sampled for the first time. The PCB and total VOC concentrations reported for this group of wells are presented in Tables 3-9 and 3-10 and on Figures 3-19 through 3-23.

No substantive differences in the general distribution of PCB- and VOC-contaminated groundwater were noted between the 2010 sampling event results and the samples collected in 2000. In general, a region of PCB- and VOC-contaminated groundwater extends from the Site to the southwest toward the Hudson River. The higher PCB and VOC concentrations are generally found in the vicinity of the former manufacturing buildings and decrease in a southwesterly direction. The TDCS is located within the central portion of the region of contaminated groundwater downgradient from the former manufacturing buildings.

As indicated in Section 3.1.3 the southern boundary of the zone of capture is located south of monitoring well V-114 and monitoring well cluster PW-2 and north of monitoring well cluster PW-1. Water quality data from the monitoring wells south of the southern capture boundary do not indicate that DNAPL is present in groundwater south of the capture zone boundary. Total PCB concentrations in samples from monitoring well cluster PW-1 ranged from a minimum of 0.105 μg/L in Upper Snake Hill Shale well PW-1A to 1.056 μg/L in the Glens Falls Limestone well PW-1E. Further south, samples from Glens Falls and Isle La Motte Limestone monitoring wells V-212, V-312, V-213 and V-313 had similar low-level total PCB concentrations ranging from a low of 0.0183 μg/L in well V-312 to a high of 0.222 μg/L in well V-212. The pattern of VOC concentrations in samples from the wells south of the capture zone boundary is similar to the PCB concentrations indicating only dissolved-phase concentrations in the southern off-site area. Now that the TDCS is operating contaminant concentrations at these locations south of the capture zone should decline.

### 3.4 IMPACT ON WATER TREATMENT PLANT

Eighteen months of operation data continue to confirm that the increased groundwater extraction rate and any associated water quality changes that resulted from construction and operation of the TDCS are well within the capacity of the on-site water treatment plant.

# 4 SUMMARY OF PHASE THREE CONSTRUCTION COMPLETION

The first three phases of TDCS construction are described in the Phase One, Phase Two and Phase Three Hydraulic Monitoring Reports, (GeoTrans, 2008a, 2009 and 2010). Additional components to Phase Three were recommended in the Phase Three Hydraulic Monitoring Status Report (GeoTrans, 2010). The additional components were recommended to be implemented in 2010 prior to submittal of the final Phase Three hydraulic monitoring report and included:

- Convert probe hole PH-2 to a multi-level piezometer;
- Install a Lower Snake Hill Shale monitoring well (V-114) at the V-14BD, V-214 well cluster; and
- Convert GL&V former production wells (PW-1 and PW-2) to multi-level monitoring wells.

GE completed the above listed actions in 2010 and performed additional TDCS construction-related tasks including:

- Constructed a permanent pumping station at the base of the shaft;
- Installed permanent piping from the shaft collar to the John Street utility tunnel;
- Installed piping and a temporary pump in the TDCS DNAPL Sump and collected a 55-gallon sample; and
- Diverted the Tailrace Tunnel discharge to the TDCS using the former casing of well HF-303.

This section describes these and other additional Phase Three actions and includes the final geologic maps, extensometer borehole logs, final probe hole logs, observations of PCB DNAPL presence during the TDCS construction, and record drawings for TDCS construction Phases One, Two, and Three.

## 4.1 CONVERT PROBE HOLE PH-2 TO MULTI-LEVEL PIEZOMETER

The installation of an additional multi-level piezometer, PZ-202, in the existing probe hole PH-2 at the end of Tunnel segment 2 was approved by NYSDEC on February

12, 2010 (NYSDEC, 2010, verbal communication) and the work was completed on March 2 and 3, 2010. The PZ-202 installation included adding a second multiplexer (MUX-2) and signal cable to the data logger. With the addition of PZ-202, the TDCS piezometer system consists of six multi-level vibrating wire piezometers, fully grouted, with an automated data acquisition system. Refer to TDCS Plan and Sections on Figures 4-1 through 4-4 for piezometer locations. Refer to Appendix E for a narrative description, installation data, figures, borehole core logs and geophysical logs for the piezometers.

## 4.2 NEW MONITORING WELLS SOUTH OF TDCS

A new monitoring well (V-114) was installed to a depth of 216 feet in the V-14BD, V-214 cluster. The new well V-114 was drilled in June 2010 and the well installed in the Lower Snake Hill Shale in September 2010. The two former production wells, PW-1 (depth 283 feet) and PW-2 (depth 303 feet) located on the GL&V property (refer to Figure 4-5) were converted into multi-level monitoring well clusters. PW-1 and PW-2 were installed prior to the 1970s, the exact date is unknown. The use of the production wells ceased in the mid-1970s. The Bedrock Feasibility Study report (GeoTrans, 2001), recommended that the two former GL&V production wells be converted to multi-level monitoring wells. PW-1 was converted to a 5-well cluster and PW-2 was converted to a 6-well cluster in September 2010. Refer to Figure 4-5 for new monitoring well locations and refer to Appendix F for a narrative description of the well installation, core logs, geophysical logs, and well construction diagrams.

## 4.3 TDCS DRAIN WELLS

The twenty drain wells were drilled and installed in early 2009 have been open and flowing since May 9, 2009. Refer to Appendix G for data on drain well installation, figures and flow testing data. Flow measurements from the drain wells were collected during entries into the TDCS. Groundwater samples were collected from the drain wells in November 2009 and February and September 2010. The results and discussion of the drain well flow measurements and groundwater sampling and testing are included in Section 3.

## 4.4 PERMANENT TDCS PUMPING SYSTEM

The temporary pumping system for the TDCS that was left in-place by the TDCS Tunnel Contractor proved to be unreliable and was upgraded in 2009. The pumping system upgrade involved removing the temporary TDCS pumps, decommissioning of the pre-treatment system, installation of a permanent deck over the TDCS sump, installing new pumps in the TDCS Sump and installation of new piping at the ground surface from the TDCS Shaft to the discharge piping in the Utility Tunnel beneath John Street. The decommissioning of the pre-treatment system and installation of the new TDCS pump system was performed in the summer and fall of 2009. The new pump system was commissioned in November 2009. Refer to Appendix H for a description of the permanent pump system installation and related figures and details.

## 4.5 TDCS DNAPL SUMP

The DNAPL Sump, which is contained within the TDCS sump, is smaller (2 feet by 8 feet) than the TDCS Sump and is 2 feet deeper than the bottom of the TDCS Sump. The DNAPL Sump provides a catchment to allow any free DNAPL to accumulate for collection. Since May 2009, the sump has been inspected on several occasions, but no DNAPL has been observed. In September 2010, a pump system was installed to draw water from the bottom of the DNAPL Sump into a 55-gallon barrel. One barrel was filled and was allowed to settle for a period of two weeks. The results showed that no observable DNAPL was present, thereby indicating that there had been no significant DNAPL accumulation in the DNAPL Sump.

## 4.6 TAILRACE TUNNEL DRAIN TO THE TDCS

A drain connecting the existing Tailrace Tunnel to the TDCS was constructed using the well casing of the monitoring well HF-303 which had previously been severed during the excavation of Workroom 1-1. As a result of the accidental destruction of the HF-303 casing within the TDCS, the HF-303 well head was relocated from the Tailrace Tunnel to TDCS Workroom 1-1 in July 2008. In February 2010 the former well head for HF-303, which was located in the Tailrace Tunnel, was cut down to the invert level of the Tailrace Tunnel to provide gravity drainage from the Tailrace Tunnel to the TDCS and allow shutdown of the Tailrace Tunnel lift station pump. All Tailrace Tunnel recovery wells now flow directly via the new gravity drain to the TDCS. Refer to Appendix (I) for additional discussion and figures.

## 4.7 TDCS EXCAVATION SPOILS

The excavated shot rock from the TDCS Shaft and Tunnels was removed from the TDCS after each round of blasting and placed in piles in designated bins on the spoils structure for PCB sampling. The shot rock spoil from every blast was sampled and analyzed for PCB. Five samples were taken at locations from each spoil pile. The PCB concentration of spoils samples determined the classification of the spoil materials and the ultimate disposition location. Refer to Appendix J for an additional description and summary of blast history and PCB spoil test results.

## 4.8 GEOLOGIC MAPPING SUMMARY

Geologic mapping was performed during the construction of the TDCS Shaft and Tunnels and included collection of geologic structural orientation data. The geologic mapping data that were collected during the TDCS excavation were previously presented in the form of preliminary Geologic Maps (GeoTrans, 2009). The Final Geologic Maps have been completed and are included in Appendix K. Also included in Appendix K are a discussion of the geologic mapping, geologic discontinuity data and analysis.

## 4.9 EXTENSOMETER BOREHOLES

Extensometers were installed at the Boralex Hudson Falls Hydroelectric Project. Two extensometers were installed at the dam and one extensometer was installed near the powerhouse as part of the geotechnical monitoring program. Refer to Appendix L for installation figures, drill logs and geophysical logs for extensometer boreholes. Monitoring data from the extensometers were included in weekly status reports submitted to NYSDEC during construction.

## 4.10 PROBE HOLES

Probe Holes PH-1 and PH-2 were drilled in a southerly direction from Tunnel 2, Workroom 2-1. Both holes were 300 feet long. Details of the drilling and groundwater sampling and testing are contained in the Phase Three hydraulic monitoring report (GeoTrans, 2010). Installation figures, core logs, and the table of results of the rock core and groundwater samples and PCB analyses for PH-1 and PH-2 are included in Appendix M

## 4.11 RECORD DRAWINGS

The record drawings for the construction of the TDCS Phases One, Two, and Three (Shaft, Tunnels, and Drain Wells and Piezometers) are included in Appendix N.

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# 5 TDCS OPERATION, MAINTENANCE AND MONITORING

TDCS operation, maintenance and monitoring (OM&M), which began in May 2009, are described in this section. Operation activities included normal TDCS operation and response to power outages and heavy rainfall runoff events. Maintenance activities included TDCS Entries for maintenance, inspections, and pump repairs in February, March, April and September 2010. TDCS OM&M Entry Procedures have been revised for each entry since May 2009 with the goal of continuous improvement. Maintenance activities also included establishing equipment spares for the TDCS pumping system and performing Utility Tunnel Roof Spall repairs and underpinning. Monitoring activities included collection of samples and measuring discharge from the drain wells, measuring DNAPL recovery from probe hole PH-1 and making observations of DNAPL accumulation in the floor trench drains.

During TDCS Construction Phases 1, 2 and 3 (September 2007 to May 2009) the TDCS General Contractor (MO-JV) provided daily access to the shaft and tunnels using cranes and personnel cages. On May 15, 2009, the final inspection of the underground work was completed, the three phases of TDCS construction were deemed to be completed, and the TDCS was turned over to the Owner. At that time GeoTrans Inc. (now Tetra Tech GEO) assumed responsibility for the OM&M of the TDCS. Current access to the TDCS is by cranes and personnel cages, but not on a daily basis. The TDCS is a Permit-Required Confined Space and provisions for emergency rescue during the infrequent TDCS entries have been established. This section of the report provides an overview of the TDCS OM&M events and activities since May 15, 2009. Refer to Table 5-1 TDCS OM&M Log for a chronology of TDCS Entries and related activities and events since May 15, 2009. For additional detailed narrative regarding TDCS OM&M refer to Appendix O.

Planning for post-construction OM&M began in December 2008 and arrangements with the TDCS Access Contractor and the Confined Space Rescue Team were in-place before May 15, 2009. Following the completion of Construction Phase Three - Drain Wells and Piezometers, and during the demobilization of the TDCS General Contractor, the current TDCS Access Contractor, Alpine Construction, began mobilizing equipment including a backup generator, personnel cages, cranes, decontamination trailer and tool and supply trailer to the Site. The current requirements for TDCS Entry include having a primary crane and a backup crane each with operators, personnel cages and an on-call Confined Space Rescue Team which is provided through a subcontract with the Glens Falls Fire Department.

Inspections are conducted during every entry into the TDCS to document the existing condition and the short term stability of the TDCS so that workers can safely access the TDCS for OM&M activities. The inspections are primarily visual and include the access shaft, tunnels, utility support brackets and hangers, ventilation ducting, electrical panels and cables, and piping for compressed air supply, fresh water supply and sump pump discharge piping. The tunnel roof integrity inspections are physical inspections that involve sounding the tunnel roof and the controlled removal of potential loose rocks by scaling with long pry bars. The inspections of the TDCS have been performed by qualified engineers, geologists and electricians. The inspections are conducted prior to the entry of workers into the TDCS with the focus and purpose of identifying and eliminating conditions that may present immediate hazards to workers. Since May 2009, the results of the periodic inspections have shown that the overall condition of the TDCS facilities appears to be good. However, there are items that warrant future attention. These items include features of the TDCS that were installed for the short-term purpose of facilitating TDCS construction and were not designed for a long-term service life. They include shotcrete lining in the shaft, electrical panels in the bell-out, utility lines, support brackets and hangers. The Phase 4 improvements to the TDCS are expected to address these features.

Residential air monitoring was performed during each planned TDCS Entry. The air monitoring was performed at two locations (Figure 5-1) for each 24-hour period worked in the TDCS shaft. The monitoring was done to document the effects of the TDCS ventilation system discharge on nearby residences. Composite air samples were collected in a polyurethane foam sorbent tube using a Sensidyne GilAir 5 RC™ Air Sampling Pump. The sampling pumps were calibrated prior to each sampling period and then placed in a bird house and hung in a tree and on a fence at sampling locations Res 1 and Res 2, respectively. The samples were analyzed by EPA Method TO-10A/8082.

The sampling documented that PCB air concentrations during the TDCS entries were below the established Hudson River Quality of Life (QOL) guidance value of 110 $ng/m^3$, in all but three of 52 samples. The air monitoring results are presented in Table 5-2.

During the five-day September 2010 sampling event, one of the Res 2 samples was not analyzed because the sampler had been destroyed by vandals. The Res 2 sample location was moved across the street from the old location to reduce the potential for vandalism.

# 6 GENERAL OBSERVATIONS AND CONCLUSIONS

## 6.1 General Conclusions Related to Achieving Groundwater Remedy Performance Goals

Groundwater monitoring data collected during the first 18 months of TDCS operation provide evidence that the goals for the Site groundwater remedy are being achieved. Potentiometric data and increases in Site-wide groundwater recovery rates provide evidence that construction and operation of the TDCS has resulted in a substantially larger hydraulic capture zone than was created solely by the IRM groundwater recovery wells and collection sumps. Potentiometric data support the conclusion that construction and operation of the TDCS has reversed vertical hydraulic gradients adjacent to and beneath the Hudson River, thereby capturing contaminated groundwater that previously discharged to the Hudson River, as well as inducing infiltration of Hudson River water into the underlying Snake Hill Shale and capture by the TDCS Potentiometric data and groundwater quality data indicate that the hydraulic capture zone created by the groundwater remedy extends beyond the known limits of DNAPL. Groundwater flow within the hydraulic capture zone is toward the TDCS and on-Site extraction wells, thereby preventing or minimizing PCB migration to the Hudson River as well as preventing or minimizing the migration of contaminated groundwater from the Site.

## 6.2 Observations and Conclusions Regarding Additional Phase Three Data Collection Activities

- The new multi-level piezometer PZ-202 and monitoring well V-114 are providing additional reliable information regarding potentiometric heads in the Lower Snake Hill Shale in the zone below the Hudson River level.
- The new multi-level monitoring well clusters installed in former GL&V production wells, PW-1 and PW-2, have expanded the Upper, Middle and Lower Snake Hill Shale and the Glens Falls Limestone water level and water quality monitoring network further to the south of the Site.
- The PCB and VOC concentrations in groundwater samples collected from the drain wells has provided information regarding the spatial extent of contaminated groundwater and DNAPL with respect to the TDCS hydraulic capture zone.

- TDCS DNAPL Sump inspections and pumping have indicated that some of the PCB DNAPL collected by the TDCS is present as an emulsion and does not readily separate from the water.
- Creating a gravity drainage pathway from the Tailrace Tunnel to the TDCS has allowed the Tailrace Tunnel lift station to be shut down. However, during high runoff or high river flow events, there is potential for a substantial increase in the amount of water that drains to the TDCS and the possibility of exceeding the TDCS pumping capacity.

### 6.3 TDCS OM&M Observations and Conclusions

- The multiple failures of the TDCS temporary pump system left in-place by the contractor at the end of Phase Three construction resulted in the need to advance the schedule for installation of the permanent vertical turbine pump system.
- The vertical turbine pumps have proven to be more reliable than the temporary pump system that was left in-place by the contractor at the end of Phase Three construction.
- The installation of vertical turbine pumps resulted in other needed improvements to the TDCS including installation of a permanent deck over the TDCS Sump, replacement of the temporary TDCS discharge piping, removal of the pre-treatment tanks, building an enclosed structure for the TDCS electrical components and installing an Ethernet communication link from the TDCS to the on-Site WTP control room.
- The required number of entries into the TDCS for maintenance has been significantly reduced since the installation of the permanent pumps. It is expected that future TDCS entries for maintenance will only be required at six-month intervals for pump motor lubrication.
- The engineering inspections of the TDCS have indicated that the condition of the shaft and tunnels is good.
- The tunnel roof sounding and scaling program is an essential component in the long term condition assessment and maintenance of the TDCS tunnels and has made the tunnels safer through the controlled removal of remnant loose rock.

- Power outages that have occurred at the TDCS have been successfully managed by the manual start-up of the back-up TDCS generator and manual transfer switching of the power feed from the electrical grid to the back-up generator.
- Heavy rainfall events produce street run-off that enters the Site from along Allen Street and runs off the Site to the south onto GL&V property and to the north onto John Street Extension. The run-off water may also enter the TDCS at the shaft collar.
- The TDCS pumping system normally has one pump operating and discharging at approximately 50 gpm. During the heavy rainfall event of September 2010 all three TDCS pumps were operating with a total discharge rate of over 300 gpm.
- There is a structurally deficient roof support beam directly above the TDCS discharge piping in the utility tunnel beneath Allen Street. The utility tunnel runs between the TDCS Site and Building 1.
- Residential air quality monitoring has been performed since August 28, 2009 at two locations (Res 1 and Res 2) for 26 days of TDCS entries resulting in a total of 52 samples. Only 3 of the 52 samples had PCB concentrations greater than the Hudson River QOL of 110 ng/L.

# 7 RECOMMENDATIONS FOR CONTINUED OPERATION, INSPECTION, MONITORING, AND PERFORMANCE EVALUATION

The recommendations presented in the following sections were developed to address the observations and conclusions presented in Section 6. Recommendations regarding optimization of the recovery system are presented in Section 7.1. Section 7.2 presents recommendations relative to the long-term monitoring of the groundwater remedy. Revisions to the TDCS Phase Four design are discussed in Section 7.3. Section 7.4 presents recommendations relative to the TDCS operation and maintenance, and a schedule for future deliverables is presented in Section 7.5

## 7.1 RECOVERY SYSTEM OPTIMIZATION

The performance monitoring of the bedrock groundwater remedy provides evidence that the TDCS has created a large hydraulic capture zone that overlaps with many of the previously existing recovery wells. As a result, it is no longer necessary to operate all of the recovery wells to maintain the capture zone. Therefore, to simplify operation of the Hudson Falls recovery system we recommend that selected recovery wells located within the TDCS capture zone, be shut down and the pumping systems eventually decommissioned. The decommissioned recovery wells will be maintained for use as monitoring wells. In addition, we recommend that the higher yield recovery wells which have also been consistent DNAPL producers be redeveloped and, if possible, their pumping rates increased.

Recovery wells that are recommended for shut down are those that are within the TDCS capture zone, have low pumping rates and low DNAPL recovery rates. It is expected that the decrease in groundwater recovery due to shut-down of the proposed wells would be offset by increases in groundwater extraction rates from the remaining wells and the TDCS. The safety of accessing wells for maintenance was also a consideration in the recommendations. Table 7-1 lists the recovery wells that we recommend be shut down, their 2010 groundwater recovery rate, their 2010 cumulative DNAPL recovery and a summary of the rationale for shutting them down. The recovery wells recommended for shut down are highlighted on Figure 7-1.

The following is a well-by-well summary of the principal reasons for recommending a shut-down of that well.

- HF-45BD: Well HF-45BD is within the capture zone of the TDCS. The water level in HF-45BD is now below the low-level sensor in the well. The well has not pumped since 2007. Prior to 2007 the average pumping rate was approximately 0.1 gpm. Only an un-measurable trace of DNAPL was collected from HF-45BD in 2010.
- HF-54BS: Well HF-54BS is within the capture zone of the TDCS. The 2010 average pumping rate from HF-54BS was 0.45 gpm, or about 1 percent of the average 2010 groundwater extraction rate by wells. The total 2010 DNAPL recovery was 5.75 liters, or 1 percent of the total 2010 DNAPL recovery from the Site. The DNAPL recovery rate from this well has been declining since 1999. Given the small volume of DNAPL collected in 2010 it is likely that DNAPL in the area of this well is not mobile under non-pumping conditions and only enters the well as a result of the groundwater pumped from the well.
- HF-63BD: HF-63BD is located within the capture zone of the TDCS. The 2010 average pumping rate was 0.42 gpm, or less than 1 percent of the average 2010 groundwater extraction rate by wells. The total 2010 DNAPL recovery was 2.9 liters, or about 0.5 percent of the total 2010 DNAPL recovery from the Site. Less than 80 liters of DNAPL have been collected from this well since 1997. Given the small volume of DNAPL collected in 2010 it is likely that DNAPL in the vicinity of this well is not mobile under non-pumping conditions and only enters the well in response to the groundwater pumping from the well.
- HF-65BD: This well is located within the capture zone of the TDCS. The 2010 average pumping rate was 0.22 gpm, or about 0.5 percent of the average 2010 groundwater extraction rate by wells. The total 2010 DNAPL recovery was 2.9 liters, or about 0.5 percent of the total 2010 DNAPL recovery from the Site. The total volume of DNAPL collected from this well since 1995 was approximately 100 liters. It is likely that

DNAPL in the vicinity of this well is not mobile under non-pumping conditions and only enters the well in response to the groundwater pumping from the well.

- OBG-1: OBG-1 was installed to relieve groundwater pressure on the up gradient side of a test grout curtain. OBG-1 is located within the TDCS capture zone. The average pumping rate in 2010 was 0.01 gpm and no DNAPL was collected in 2010. Operation of this well provides no demonstrated benefit to the Site groundwater remedy.
- RW-101: RW-101 is located within the TDCS capture zone. The 2010 average pumping rate was 0.69 gpm, or about 1.5 percent of the average 2010 groundwater extraction rate by wells. The total DNAPL recovery in 2010 was only 0.05 liters. Since pumping began in 1996 approximately 16 liters of DNAPL have been recovered from RW-101. It is likely that DNAPL in the vicinity of this well is not mobile under non-pumping conditions and only enters the well in response to the groundwater pumping from the well.
- RW-102: RW-102 is located within the TDCS capture zone. The 2010 average pumping rate from RW-102 was 0.52 gpm, or about 1 percent of the average 2010 groundwater extraction rate by wells. The total DNAPL recovery in 2010 was 4.75 liters, or less than 1 percent of the total 2010 DNAPL recovery from the Site. Approximately 85 liters of DNAPL have been collected from RW-102 since 1996 when pumping began. There was no substantial change in DNAPL recovery from RW-102 resulting from the construction or operation of the TDCS. It is likely that DNAPL in the vicinity of this well is not mobile under non-pumping conditions and only enters the well in response to the groundwater pumping from the well.
- Tailrace Tunnel Recovery wells: Recovery wells RW-106, RW-107, RW-108 and RW-109 are located in the tailrace tunnel. The Tailrace Tunnel is a potentially hazardous work environment, due to the potential for falling rock. Maintenance of the Tailrace Tunnel wells must be done under potentially dangerous working conditions and is a recognized safety

hazard to Site workers. The Tailrace Tunnel is located within the TDCS capture zone. The tail race tunnel recovery wells all have low groundwater pumping rates. The 2010 average pumping rates ranged from 0.11 to 0.58 gpm and the 2010 total pumping rate from the four recovery wells was only 1.49 gpm, or about 3 percent of the average 2010 groundwater extraction rate by wells. All of the Tailrace Tunnel recovery wells experienced an increase in DNAL recovery rates during TDCS tunnel excavation. The DNAPL recovery rates from wells RW-107, RW-108 and RW-109 are now less than they were during the two-year pre-construction baseline monitoring period The 2010 total DNAPL recovery volumes from RW-107, RW-108 and RW-109 were 3.57, 6.23, and 1.77 liters respectively. The 2010 total DNAPL recovery from RW-106 was 35.07 liters. The DNAPL recovery rate from RW-106 has declined since the TDCS began full-scale operation. The recovery rate is greater than it was during the pre-construction baseline monitoring, however it is less than the DNAPL recovery rate observed in the 1999-2001 time period. We believe that any mobile DNAPL that remains in the bedrock fractures in the vicinity of the tailrace tunnel would flow toward and be captured by the TDCS.

- Overburden Recovery Wells: GE is proposing to decommission seven overburden recovery wells; RW-1, RW-3B, RW-4, RW-5, RW-6, RW-7 and MH-4. Together these wells had a total 2010 average groundwater recovery pumping rate of 2.45 gpm, or about 5 percent of the average 2010 groundwater extraction rate by wells. The total 2010 DNAPL recovery rate from these seven wells was 1.64 liters, or about 0.3 percent of the total 2010 DNAPL recovery rate. All of these overburden recovery wells exhibited an increase in DNAPL recovery resulting from the dewatering caused by construction and operation of the TDCS, but except for RW-1, the DNAPL recovery rate in the individual wells has declined to zero. The groundwater flow in the overburden is downward into the Snake Hill Shale and the shale is within the TDCS capture zone. Shutting down these seven overburden recovery wells would not adversely impact the performance of the Site groundwater remedy.

A systematic plan for shutting down the recommended recovery wells will be submitted to NYSDEC for review and approval. The plan will include:

- A proposed sequence for recovery well shut-down;
- A recovery well shut-down monitoring procedure;
- Decision criteria for recovery well decommissioning or reconfiguration to a monitoring well; and
- A recovery well decommissioning or reconfiguration procedure.

We are also recommending that certain existing wells be re-developed, and, if possible their pumping rates increased. Wells recommended for redevelopment and possible pumping rate increases are those that currently have relatively high groundwater pumping rates and collect DNAPL on a regular basis. Table 7-2 lists the wells recommended for redevelopment along with the rationale for well redevelopment.

## 7.2 LONG-TERM MONITORING

Now that the Site bedrock groundwater remedy is fully operational, GE will develop a long-term monitoring plan for NYSDEC review and approval. The plan will specify the types and frequency of monitoring as well as the frequency of reporting.

Prior to developing the detailed long-term monitoring plan we recommend the following changes to the current monitoring program to be implemented now:

- Reduce the frequency of manual bedrock monitoring well water level measurements from weekly to quarterly;
- Reduce the frequency of Hudson River water column sample collection at the Boat Launch from weekly to monthly;
- Reduce the frequency of sampling from off-site monitoring wells OS-215 and OS-316 from annually to once every five years; and
- Collect a second round of samples from recently completed monitoring well V-114, and the PW-1 and PW-2 monitoring well clusters.

The frequency of water level measurements in the bedrock wells was increased from quarterly to weekly prior to opening the drain wells to better monitor the water level changes resulting from starting full-scale operation of the TDCS. The rate and magnitude of water level changes have decreased as the groundwater system has approached a new equilibrium. As a result, the water level measurements no longer need to be collected as frequently. Hudson River water column samples have been collected approximately weekly at the Boat Launch sampling station since 1996. Results of sampling and analysis since the TDCS operation began indicate that PCB concentrations in Hudson River water column samples are declining. Weekly sampling is no longer necessary, and monthly monitoring is sufficient to track this trend. Samples have been collected from off-site wells OS-215 and OS-316 annually since they were completed in 2000. No PCBs or Site-related VOCs have been detected in any of those samples. Based on these results, annual sampling is no longer necessary. We believe the sampling frequency for these wells can be reduced to once every five years. The recently completed monitoring well clusters PW-1 and PW-2, and monitoring well V-114, located south of the TDCS, have only been sampled once since they were completed in 2010. We recommend sampling these wells in 2011 to provide a second data set for comparison to the original sampling results.

### 7.3 PHASE FOUR CONSTRUCTION

Portions of the planned Phase Four construction were completed early to enhance the full-scale TDCS operation. Components of Phase Four construction that have been completed include:

- Installation of a permanent TDCS pump station;
- Installation of permanent piping from the TDCS to the John Street utility tunnel;
- Installation of Ethernet communications between the TDCS and the WTP control room; and
- Procurement and hook-up of an emergency backup generator.

Based on the nearly two years of full-scale operation, it is evident that the TDCS can be operated with limited entries into the TDCS. Currently, scheduled entries occur every six months. This frequency of tunnel entry is dictated by the manufacturer's recommended pump maintenance schedule. The infrequent TDCS entries make installation of the permanent elevator included in the Phase Four design unnecessary. Many of the other Phase Four construction components, such as the HVAC system and building, were included to protect the elevator and its working components. Based on the experience of operating the TDCS in its current configuration, GE is reconsidering the scope of Phase Four construction. GE will develop a conceptual plan for Phase Four construction that is integrated with the final Site restoration. The conceptual plan for Phase Four construction will include a schedule for completing the design and implementing the revised Phase Four construction.

### 7.4 TDCS OM&M

The following are itemized recommendations for ongoing operation and maintenance of the TDCS in its current configuration.

- Monitoring Well Cluster PW-2:
  - Close up the 23-inch diameter annular space around the well pipes to improve safety during well monitoring activities.
- Tailrace Tunnel Drain to TDCS:
  - Install a water level sensor in the Tailrace Tunnel (TRT) to provide warning of high water conditions that could potentially flood the TDCS.
  - Install a strainer to prevent clogging of the TRT Drain.
  - Develop an Action Plan for high water conditions and action levels to start-up the TRT Lift Station and shut down flow to the TDCS.
  - Evaluate the high rainfall and run-off event of September 30, 2010, and its effect on the TRT water levels.
  - Evaluate the TRT lift station pump (it has been off for 9 months) to determine if it needs to be exercised on a regular schedule.
- TDCS Equipment Spares:
  - Evaluate the need for a spare vertical turbine pump.
- Wastewater Equalization and Storage:
  - MODU Tanks in Buildings 2 and 4 - Confirm the condition and integrity of the MODU Tank liner membrane and make any repairs or replacements as appropriate to prevent leaks.

- Consider construction of a permanent equalization tank near the TDCS shaft that is of sufficient size to handle high flows during heavy run-off events. There is currently insufficient run-off storage volume on-site for unusual run-off events associated with significant rainfall or snow melt events.

- Site Improvements in the vicinity of the TDCS Shaft:
  - Prevent street and surface water run-off from entering the property adjacent to the TDCS shaft, especially along the Allen Street property line.
  - Prevent surface run-off from leaving property adjacent to the TDCS shaft.
- Utility Tunnel Improvements:
  - Address the structurally deficient areas of the utility tunnels, in which a failure could compromise personnel safety or the proper containment of contaminated water (i.e. pipelines etc.). Structurally deficient areas should be repaired.
- TDCS Shaft and Tunnels:
  - Conduct inspections of the TDCS shaft and tunnels every six months. The inspections should be performed by a qualified individual such as Engineering Geologist, Geotechnical Engineer, or an equivalent person.
  - The temporary shotcrete lining above the bell-out in the shaft should be evaluated for long-term performance as part of future condition assessments.
  - Conduct Tunnel Roof Integrity Testing and Scaling every six months. Refer to recommended procedures included in the TDCS Entry report for September 2010.
  - Conduct detailed inspections of all TDCS systems annually. The temporary facilities in the TDCS including ventilation, fresh water piping, compressed air piping, sump pump discharge piping and the electrical system should be evaluated and improvements or upgrades considered as part of future condition assessments and redesign activities.

## 7.5 SCHEDULE

The schedule for GE to submit the recommended plans is as follows:

- Recovery System Optimization Plan July 1, 2011
- Phase Four Construction Conceptual Design & Plan November 4, 2011
- Long-term Monitoring Plan March 9, 2012

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