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July 5, 1984
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E. I. duPont de Nemours & Co., Inc.
Niagara Plant
26th Street & Buffalo Avenues
Niagara Falls, New York 14302

Attention: Mr. Timothy B. Van Domelen
Engineer - R & D

PHASE II REMEDIATION STUDIES
NIAGARA PLANT
NIAGARA FALLS, NEW YORK

Gentlemen:

We are pleased to present herein this Report of our Phase II Remediation Studies conducted for the Niagara Plant, Niagara Falls, New York. The objectives of this study and an outline of the scope of work were defined in DuPont's letter dated May 21, 1984, to the New York State Department of Environmental Conservation. Phase II remediation studies were conducted to evaluate the available remediation techniques in relationship to technical feasibility, environmental effectiveness, impact on site operations and associated costs. As a result of these studies, a conceptual remedial action program has been developed and is presented herein.

We sincerely appreciate the opportunity of providing these services to you on this project. If you have any questions, please contact us.

Very truly yours,

WOODWARD-CLYDE CONSULTANTS

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PHASE II REMEDIATION STUDIES
NIAGARA PLANT
NIAGARA FALLS, NEW YORK

Submitted to:

E. I. DUPONT DE NEMOURS & CO., INC.

Niagara Falls, New York

Prepared by:

WOODWARD-CLYDE CONSULTANTS

Plymouth Meeting, Pennsylvania

EXECUTIVE SUMMARY

A Phase II Remediation study was conducted to determine which remedial action alternative would most cost effectively contain overburden contamination at the DuPont Niagara Plant site. This report presents the findings relative to the screening of remedial technologies, the identification of remedial action alternatives and the evaluation of those alternatives.

Information from previous geohydrologic and remediation studies was used as the basis for this report. Results of the geohydrologic studies indicated the extent and nature of contamination and contaminant migration at the plant site. Remediation studies resulted in the identification of candidate remediation technologies, and the plant areas where they were applicable.

As part of these Phase II Remediation studies, three areas were identified as requiring remediation: the east plant area, the west plant area, and the west plant maintenance area. The west plant maintenance area was considered separately from the east and west plant areas because of its location and the nature of contamination. Remedial technologies considered in the west plant maintenance area were excavation and disposal, and capping. Capping was selected as the recommended remediation approach based on lower costs and acceptable environmental effectiveness. The remainder of the Phase II remediation report deals with the east and west plant areas only.

Based on screening of remedial technologies, hydraulic controls and passive containment were considered appropriate for application at the plant site. Drain tiles were selected as the best method of hydraulic control and soil-bentonite slurry cutoff walls as the best method of passive containment.

Five remedial action alternatives were identified for the east plant area and four for the west plant area:

EAST PLANT AREA

1. Drain tile only
2. Drain tile with downgradient cutoff wall along Adams Avenue.
3. Drain tile with downgradient cutoff wall along Buffalo Avenue.
4. Drain tile with upgradient cutoff wall along Niagara Parkway.
5. Drain tile with circumscribing cutoff wall.

WEST PLANT AREA

1. Drain tile only.
2. Drain tile with downgradient cutoff wall along Niagara Parkway.
3. Drain tile with upgradient cutoff wall along Buffalo Avenue.
4. Drain tile with circumscribing cutoff wall.

Computer model simulations were performed on each of the nine alternatives to assess their impact on the overburden groundwater regime, and to determine their hydraulic effectiveness. Flows which would be required for water treatment were then generated for each alternative. Based upon the modeling, downgradient cutoff walls were eliminated from further consideration, because they did not improve the efficiency of the drain tile system. Final consideration was therefore given to three east plant area and three west plant area alternatives. Nine possible combination alternatives were generated (a 3x3 matrix).

Water treatment alternatives were evaluated over the range of flows generated for each of the nine combinations of alternatives. Based upon screening of treatment technologies, considered applicable were gravity phase separation, air stripping, vapor phase activated carbon adsorption, liquid phase granular activated carbon adsorption, bioreclamation (PACT) process, and polishing filters. Three potential treatment remediation trains were identified and evaluated. The recommended treatment train, which includes separate treatment of groundwater from the east and west plant areas, was presented as the preferred treatment train.

A cost effectiveness and performance analysis was performed which included the generation of costs associated with each of the nine combinations of alternatives. Based upon this analysis, the alternative selected as most cost effective combines the circumscribing slurry wall for both the east and west plant areas with a drain tile for hydraulic control.

Additional studies relative to groundwater flow along Buffalo Avenue are recommended due to a lack of data in this area. Although alternative groundwater flow patterns in this area do not change the recommended remedial concept, details with respect to implementation of the concept would be affected by the results of these additional studies.

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INTRODUCTION

In order to develop and implement a remediation program for the Niagara Plant, it was first necessary to conduct the appropriate engineering and geologic studies. Initial geohydrological investigations have been completed as described in our reports dated December 23, 1983 and February 17, 1984 and entitled "Geohydrologic Investigations" and "Manmade Passageways Investigations", respectively. Supplemental geohydrologic investigations are ongoing, including a report in preparation entitled "Supplemental Manmade Passageways Investigations", as well as the installation and sampling of supplemental monitoring wells. Remediation studies completed to date include an examination and compilation of available remedial action techniques as described in our "Phase I Remediation Studies" report dated April 2, 1984.

The project strategy that has been established is to actively pursue remediation of the "source" (contamination in the overburden) while concurrently conducting necessary supplemental geohydrologic investigations. The remediation investigations are, therefore, presently focused upon controlling contamination located within the overburden. The following report presents the results of our Phase II Remediation Studies.

BACKGROUND AND PROJECT DESCRIPTION

Investigations have been undertaken at the DuPont Niagara Plant to evaluate the presence and movement of suspect chemical contaminants in the overburden and bedrock groundwater flow regimes. As described in our December 23, 1983 report, groundwater in the area of the DuPont Niagara Plant site is encountered in both the unconsolidated overburden soils and the underlying bedrock. The source of the groundwater recharge for the overburden in the vicinity of the Niagara Plant site is primarily from direct infiltration of precipitation. The source of groundwater recharge in the underlying Lockport dolomite is from induced infiltration from the Niagara River and, to a lesser extent, from leakage downward from the groundwater flow regime in the overlying overburden. Inferred groundwater contours in the overburden is presented on

Plate 1. In the west plant area (west of Gill Creek), groundwater discharges toward Gill Creek and the Niagara River. Groundwater in the overburden, in the east plant area (east of Gill Creek) flows toward the northeast. In contrast, flow in the fractured rock is from the Niagara River toward the Olin production wells northwest of the site and from the Niagara River toward an groundwater discharge area to the northeast of the site.

As part of the foregoing investigations, chemical analyses were performed on groundwater samples obtained from monitoring and utility wells. Based upon field reports during well installations and groundwater sampling, as well as comparisons of specific analytical results with solubility limits, it was concluded that non-aqueous phase fluid exists at several locations throughout the plant site. Further, the relative distribution of volatile compounds was compared with locations of previous processes and events on the plant site resulting in a correlation between the process/event areas and the concentrations of individual compounds.

Potential migration of contaminants at the Niagara Plant site was also evaluated. Because of the presence of two liquid phases, the transport process is complex and governed by a number of factors including groundwater flow and geologic structure. Based upon the data available regarding contaminant concentrations and groundwater flow, the total potential volatile organic loading to the Niagara River was estimated to be approximately 100 pounds per day with approximately 50 percent arriving at the Niagara River via pumpage from the Olin production well. These data were utilized to form the basis of evaluation of the remedial alternatives discussed herein.

Our Phase I Remediation Study was conducted to identify and evaluate available remediation techniques that would be applicable to the DuPont Niagara Plant site. The Phase I report presented our findings as to the site specific applicability of remediation alternatives. Based upon our previous studies, five general areas in the Niagara Plant site were identified and included in the initial remediation study. These areas included (1) the solvent process area, buildings B-81 to B-84; (2) the building B-403 polyglycol area; (3) the west plant maintenance area; (4) the building B-44 sodium cyanide product area; and (5) the HCN incinerator area (see Plate 2 for reference). Specific alternatives for the remediation of these five areas were developed. Potential remediation technologies included excavation and disposal, passive containment techniques, active containment techniques, in-situ solidification, flushing, bioreclamation of contaminated groundwater and conventional treatment of groundwater. Table 1, derived from our Phase I Remediation Study contains a summary of the applicability of these technologies in the various areas.

SCOPE OF REMEDIATION

The objective of the remediation system(s) is to contain off site migration of contaminants through the overburden. In order to address this objective, it is first necessary to further define the study area, such that the remedial technologies identified in our Phase I report can be refined. In order to do this, a re-evaluation was made of the process/event areas and the concentration contours for volatile organics.

Presented on Plate 2 are the locations of historical processes and events indicating the five major areas previously identified. As a basis of comparison, apparent concentration contours for the C-1 compounds from the October, 1983 sampling for the A-zone are presented on Plate 3. As illustrated, the concentration of C-1 compounds is generally less than one part per million in the east plant area. The highest concentration of C-1 compounds was found to be in excess of 600 parts per million in the west plant area at well cluster 15.

Shown on Plate 4 are the apparent concentration contours for C-2 compounds from the October, 1983 sampling. As shown on this plate, the east plant area has a maximum of approximately 30 parts per million of C-2 volatile organic compounds (in the vicinity of well cluster 8). Higher concentrations were again observed in the west plant area. Maximum concentration of C-2 compounds for the October, 1983 sampling was found to be approximately 260 parts per million at monitoring well 13A.

Hence, there appears to be lower volatile organic concentrations in the east plant area and two centers of higher concentrations in the west plant area, i.e., monitoring wells 15A and 13A for C-1 and C-2 compounds, respectively. In order to further examine the contaminant distribution, an average total organic carbon (TOC) contour map was prepared using sample data from the A-zone wells. As shown on Plate 5, the highest TOC concentrations were found in the east plant area, with the maximum (greater than 500 parts per million) occurring at well number 8. The maximum TOC for the west plant area was 100 parts per million in the vicinity of well cluster 16. Although TOC has been observed to vary, the contours plotted on Plate 5 represent the average of three separate samples.

As a result of our review of the available chemistry data and groundwater distributions, it is concluded that the site remediation should be considered for three separate areas. Remediation systems should be considered for both the east and west plant areas, since these represent isolated groundwater flow systems in the A-zone. In addition, the west plant maintenance yard (see Plate 2), with predominantly inorganic contamination, should be considered separately. Hence, subsequent discussions refer to east plant or west plant remediation systems (integrating the systems where appropriate). The west plant maintenance area will be addressed separately.

WEST PLANT MAINTENANCE AREA

The west plant maintenance area is the former location of the cyanide weathering area and the current location for the handling of barium, sodium and calcium chlorides. As determined in the Phase I studies, two remediation options appear most feasible: a limited excavation of the surficial materials where suspected high concentrations of the weathering products mentioned above are located and/or surface sealing of the same area.

With the limited excavation option, backfill of the excavated area could consist of readily compactible materials to accommodate the continued use of this area. This compacted material could consist of a clay material capable of limiting precipitation infiltration or vertical penetration of future possible contaminants. Alternatively, a more granular fill material can be used to bring the area to site grade in combination with surface sealing using, for example, a bituminous liner to inhibit precipitation infiltration. Final grade would then be established to promote drainage. Surface runoff controls, such as drainage ditches and collection basins, would be an integral part of this alternative.

In order to minimize leaching of soluble contaminants to the water table, the excavation and backfill operations could conceivably be eliminated and only a surface sealing procedure affected. Again, runoff control, such as drainage ditches and collection basins, would be an integral part of this surface sealing operation. The latter approach would inhibit the downward migration of contaminants and minimize precipitation infiltration. Although the environmental impact of this option is considered less effective than the removal of the potentially contaminated surficial materials, it would abate the transport of these contaminants off-site. Additional work is in progress in this area as part of the supplemental Manmade Passageways investigation. The data obtained from this study will be used when implementing remedial alternatives. It is concluded, at this time, that the surface sealing approach be utilized at the west plant maintenance area. Inherent in the second option is lower cost due primarily to the elimination of excavation and backfill required for the first option. The remainder of the report will focus upon remediation of the east and west plant areas.

SCREENING OF REMEDIATION TECHNOLOGIES

The alternative remediation technologies considered as a result of the Phase I studies, are shown in Table 1. As a result of Phase II analyses (and the consideration of three rather than five separate areas for application of remediation technologies), a screening of these technologies has been completed and is presented below.

EXCAVATION AND DISPOSAL

As a result of Phase I studies, the use of widespread excavation and disposal as a remediation technology was eliminated. Limited area excavation was shown to be practical in the west plant maintenance area, and although possible, was not recommended in other plant areas. Limited excavation may be considered at a future date in the east or west plant areas, but it would not interfere with or change overall remediation strategies.

SOIL FLUSHING

Soil flushing is a remedial technique which involves the solubilizing of waste constituents from the contaminated medium and collecting and treating the leachate. Although this method was considered a viable alternative at the end of the Phase I studies, the following limitations were noted:

- Variability of hydraulic properties in the overburden would likely limit the hydraulic effectiveness of the system.
- Presence of non-soluble contaminants could result in limited cleanup potential.
- Downward vertical migration of contaminants caused by increased heads could occur.
- The presence of extensive building and roadway areas, as well as underground utilities, would place unacceptable constraints upon the system layout, thereby significantly reducing hydraulic and environmental effectiveness.
- Increased groundwater flows for treatment would substantially raise overall project costs.

These considerations limit both the cost and environmental effectiveness of a flushing system to such a degree as to make it impractical at this time.

ACTIVE CONTAINMENT TECHNIQUES

The function of active containment techniques (hydraulic controls) is to establish a hydraulic barrier which would control the off-site migration of groundwater, and isolate contaminated groundwater from the regional groundwater flow regime. Hydraulic barriers can be formed by pumping groundwater from or by injecting groundwater into a formation. Withdrawal of water from the groundwater regime results in the development of a locally depressed groundwater table and subsequent flow toward the pumping location. Injection of water into the groundwater flow regime results in the development of a local mound in the water table and subsequent flow away from the injection location. Both methods can result in the development of a groundwater divide which isolates the desired area of the groundwater flow regime. Hydraulic barriers upgradient of a site would function to prevent movement of groundwater into the site area, while in the downgradient areas, they would serve to contain the off-site migration of any contaminated groundwater.

The design of a hydraulic barrier can incorporate groundwater withdrawal (pumping wells or drain tiles) or injection (injection wells, seepage basins, or seepage tile systems). At the plant site, the use of pumping wells and/or a drain tile collection system are considered applicable. Incorporation of an injection system as a potential remedial system was eliminated because it would result in an increased vertical hydraulic head between the overburden and bedrock, resulting in a potentially increased contaminant loading from the overburden to the underlying bedrock zone. Also, increased groundwater gradients would result, possibly carrying contaminants off-site. In addition, flow rates for treatment of groundwater would be increased. Therefore, it is concluded that an injection system to create a hydraulic barrier is not appropriate.

To determine whether drain tiles or pumping wells are more appropriate, the following criteria have been identified: environmental effectiveness, constructability, design considerations, mechanical complexity, and cost.

- **Environmental Effectiveness:** Except as identified below, there is little difference in environmental effectiveness between drain tiles and pumping wells. Properly designed, installed, and operated they would both perform effectively as hydraulic controls. However, it must be recognized that shut-downs can occur, causing the systems to, at least temporarily, lose their environmental effectiveness. Drain tiles, because of their relative simplicity, are considered to be more dependable. In addition, drain tiles would be more effective in collecting non-aqueous phase liquids, thereby increasing the environmental effectiveness of this option.

- **Constructability:** It is proposed that drain tiles would be installed primarily in the roadway along sewer trenches already in place. Selecting this location provides good accessibility to implement construction of the drain tile system. It should be noted that although the alignment of the drain tile collection system in the roadway considerably reduces the amount of interference affecting construction, inevitably, underground utilities such as sewer laterals will be encountered and may require temporary relocation or rerouting. Therefore, some disruption of plant sewers and/or utilities could be anticipated with drain tile collection system installation because these utilities may intersect the drain tile alignment. Conversely, pumping wells could likely be installed with less disruption of normal plant activities.

- **Design Considerations:** The design of hydraulic controls must take into account the heterogeneous nature of the subsurface materials at the plant. These considerations are greatly simplified for drain tiles since their hydraulic effectiveness could be maintained for a broad range of subsurface materials. The effectiveness of wells however, is related to the nature of the materials at the specific well location. Therefore, in order to obtain desired hydraulic effectiveness, the design of pumping wells would require more data on subsurface conditions at the specific locations selected. Results of this additional testing could have a significant impact on the number and location of wells required to achieve the desired hydraulic effectiveness.

- **Mechanical Complexity:** Mechanical complexity is considered as it relates to ease of operation and maintenance. Because of the relative simplicity of drain tiles, they are considered less complex and, therefore, easier to operate and maintain than pumping wells.

- **Cost:** For costing purposes, it was assumed that eight wells in each the east and west plant areas would be required to provide a similar level of hydraulic control as the drain tile system. Present worth costs (evaluating both capital and operation and maintenance costs) were generated which indicate that a drain tile system would be approximately 50 percent less expensive than a comparable pumping system.

As can be seen, drain tiles are the preferred alternative, notwithstanding the one criterion which favors pumping wells (i.e. constructability). However, with proper planning and design, problems related to constructability of a drain tile collection system can be overcome with minimum interference with normal plant operations. Therefore, drain tiles are the recommended method for establishing hydraulic control.

PASSIVE CONTAINMENT TECHNIQUES

Consideration was given in these Phase II studies to the use of passive in-situ containment techniques at the Niagara Plant site to decrease flow rates associated with hydraulic controls, and to minimize off-site movement of contaminants within the overburden materials. The passive in-situ containment techniques considered included the use of vertical barriers to horizontal groundwater flow and horizontal barriers to limit vertical groundwater flow.

As described in our Phase I report, vertical barriers to horizontal groundwater flow could include slurry trench cutoff walls composed of soil-bentonite or cement-bentonite, grout curtain walls of cement and/or chemical composition, steel sheet piling, or vibrating beam thin cutoff walls. It was concluded that a slurry trench cutoff wall of soil-bentonite or cement-bentonite represents the best available and most cost effective technology for the vertical barrier to horizontal groundwater flow.

Consideration in these Phase II studies was given to the choice between a soil-bentonite slurry trench cutoff wall and a cement-bentonite slurry trench cutoff wall. The primary criteria to evaluate this selection are constructability, permeability and long-term performance.

- o **Constructability:** The major foreseeable problem in constructability for either type of slurry wall involves the shot rock fill materials along the river and other areas along various slurry wall alignments, as shown on Plate 6. In these areas, loss of the slurry through the sidewalls is of concern. Experience shows that in relatively open fill material such as this, the soil-bentonite slurry wall can be installed with less slurry loss, and therefore at a lower cost. Further, since the slurry is ultimately displaced for a soil-bentonite cutoff wall, additives to minimize slurry loss can be employed.

- **Permeability:** The permeability of a soil-bentonite wall ($1x10^{-6}$ to $1x10^{-7}$ cm/sec) is significantly lower than that of a cement-bentonite wall ($1x10^{-4}$ - $1x10^{-5}$ cm/sec).

- **Long-Term Performance:** Factors affecting long-term performance include the impact of contaminants upon the permeability and durability of the wall. Based upon the results of our examination of the groundwater quality data, it is concluded that groundwater, as presently characterized, could significantly increase the permeability of a cement-bentonite cutoff wall. In addition, available data regarding cement-bentonite cutoff walls in an adverse environment is limited. Likewise, the groundwater, as presently characterized, would also be expected to increase the permeability of a soil-bentonite cutoff wall. It is expected, however, that the long-term permeability increase would likely be limited to one to two orders of magnitude. If the soil-bentonite cutoff wall was designed to have a high percentage of natural, non-swelling fines, it is expected that permeability increases could be controlled.

As a result of the above considerations, it is recommended at this time that soil-bentonite slurry walls be considered for utilization at the site.

Horizontal barriers, such as a horizontal grout curtain, were investigated for use at the site to control the downward movement of contaminants below the overburden. It was concluded, however, that the use of horizontal barriers at the Niagara Plant site is not appropriate. With the large number of facilities already at the site, it would be difficult to construct a uniform grout curtain and verify its continuity. In addition, costs of a horizontal barrier are expected to be prohibitively high.

IDENTIFICATION OF REMEDIAL ACTION ALTERNATIVES

Based on the screening of remedial action technologies, alternatives for the Niagara Plant site would involve drain tiles for hydraulic control, and/or soil-bentonite slurry trench cutoff walls. These technologies can be effectively used in conjunction with one another with the primary purpose of the cutoff wall being to reduce the rate of flow to the tile drain collection system. It is necessary, therefore, to evaluate the trade-off between capital costs of cutoff walls versus reduced treatment costs. Our experience indicates that, in many cases, treatment costs are the major cost item in a given remediation scheme. Therefore, overall project costs are often lower for those remediation schemes with lowest water treatment costs.

The possible combinations of drain tile and cutoff wall configurations include drain tiles only, upgradient cutoff walls with drain tiles, downgradient cutoff walls with drain tiles, and circumscribing cutoff walls with drain tiles. Note that a circumscribing cutoff wall without drain tiles is not considered. In order to maintain an inward hydraulic gradient across the cutoff walls, and to remove water entering the system through upward migration and downward infiltration of rainfall and snow melt, drain tiles will be required.

- **Drain Tiles Only:** With drain tiles only, a hydraulic barrier would be created to minimize the movement of contaminated groundwater off-site. The location of the drain tiles for optimum hydraulic and environmental effectiveness is discussed subsequently in the section on computer modeling.

- **Upgradient Cutoff Walls:** The purpose of upgradient cutoff walls is to reduce the flow of groundwater into the site, thus resulting in reduced groundwater flow rates for treatment. The upgradient direction for the west plant site area, based upon the groundwater contours from the presently available data, is to the north and west, while for the east plant site, it is along the Niagara River and Gill Creek. The location of the illustrative representation of the upgradient cutoff walls is shown on Plate 7.

- **Downgradient Cutoff Walls:** The purpose of a downgradient cutoff wall is twofold. First, it would inhibit groundwater flow across the site and flatten the groundwater gradient in the downgradient direction, thereby increasing the hydraulic effectiveness of the groundwater collection system. In addition, it would add a measure of additional environmental effectiveness by the presence of a physical barrier to off-site groundwater flow in the event of a temporary shutdown of hydraulic controls. The downgradient direction for the west plant site is along the river, while for the east plant site it is to the northeast. The illustrative representation of location of the downgradient cutoff wall is shown on Plate 8. Plate 9 is an alternate downgradient cutoff wall scheme for the east plant area which extends off-site to Buffalo Avenue. This slurry wall would be more environmentally effective than the slurry wall along Adams Avenue in the east plant area because it would allow for the containment of more of the off-site portion of the TOC contaminant plume shown on Plate 5.

- **Circumscribing Cutoff Walls:** The purpose of a circumscribing cutoff wall is to minimize groundwater withdrawals required for hydraulic control and to provide the environmental effectiveness related to a physical downgradient barrier. Shown on Plate 10 are illustrative representations of circumscribing cutoff walls for the east and west plant site areas. Note that the more extensive downgradient cutoff wall location (Plate 9) was selected to form the circumscribing cutoff wall for the east plant area.

Table 2 contains a summary of the alternatives described above. It is noted that the alignments of the various cutoff wall alternatives presented on Plates 7, 8, 9 and 10 are for illustrative purposes only to aid in the conceptual design analyses. The selection of the preferred cutoff wall alignment would consider the location of various plant utility lines, transportation structures, etcetera such that minimum construction interference and maximum environmental effectivness is effected.

MODELING OF ALTERNATIVES

Based on remediation schemes described above and considered for further investigation, the main objectives of the modeling study are as follows:

- o to evaluate the influence on the site groundwater regime of a drain tile system and optimize system layout, and
- o to evaluate the influence of a slurry trench cutoff wall on the site groundwater regime.

To evaluate the alternatives, the Prickett-Lonnquist groundwater flow model was used. This is a widely used, well-documented, two-dimensional finite difference numerical technique which models groundwater flow. The model solves a form of the transient flow equation which allows for the inclusion of heterogeneity and anisotrophy. The numerical technique can be used for both the confined and unconfined aquifer case and to solve for both steady state and transient flow conditions. For the purposes of this investigation, the unconfined case and transient and steady-state conditions were examined. Appendix A details the model theory and assumptions.

It is important to emphasize that the modeling presented herein was conducted to verify the conceptual remediation concepts. Additional modeling will be required for final design. Data used as input for the computer modeling were obtained from previous Woodward-Clyde Consultants reports, namely, "Geohydrologic Investigation", Volumes I and II, December 23, 1983, "Manmade Passages Investigation", February 17, 1984, "Geophysical Investigation", April 11, 1984, "Phase I Remediation Study", April 2, 1984, and a report prepared internally by DuPont personnel identified as "Plant Sewer Infiltration Study Phase I", February 17, 1984. In addition, other DuPont plant drawings were utilized to determine location and invert elevations of various utility lines. A listing of the drawings utilized are presented in Table 3. Data used to generate the groundwater flow model, i.e., initial groundwater elevation contours and top of rock contours, were determined by interpolation and extrapolation of the data obtained from the above referenced reports and are presented herein on Plates 1 and 11, respectively. The data used to assign values for the average hydraulic conductivity of the modeled area were obtained from the geohydrologic investigation report dated December 23, 1983 and presented herein as Table 4.

MODEL CALIBRATION

Model calibration involves the quantification of model inputs and the "fine-tuning" of the model. The goal is to demonstrate that the model is capable of simulating some historic hydrologic event for which field data are available. The heads computed for the first run of a model usually do not match the field values; therefore, calibrating the model consists of adjusting the input data such that computed heads approximate field values. The model for these studies was calibrated as described below.

The east and west plant areas were modeled separately as unconfined groundwater regimes of variable thickness. The thickness of the overburden in the west and east plant areas ranged from six to 14 feet and from seven to 23 feet, respectively (see Plate 12). A uniform hydraulic conductivity of $1x10^{-2}$ cm/sec was used for both areas. The boundaries were placed at the perimeter of the respective areas and were established as constant head. With a constant head boundary, the head at the boundary nodes was not allowed to vary with changes in stress on the system. For the purposes of this study, the boundary head was fixed by assigning high storage coefficients at the boundary nodes. It is noted that the northern/eastern boundaries of the east plant area and the northern/western boundaries of the west plant area were positioned sufficiently far from the imposed stress conditions that these boundaries were not affected by the imposed stress conditions.

Recharge through infiltration of rainfall and snow melt was based on the following assumption. Using an average rainfall amount of 35 to 40 inches per year, it was assumed that about 20 to 25 percent could be recharged to the overburden groundwater regime over approximately 50 percent of the east plant area and 25 percent of the west plant area.

The initial head values were entered at appropriate nodes to simulate the water table configuration presented on Plate 1. After inputting the initial conditions, the model was allowed to run to equilibrium using a predetermined time step and an allowable convergence error. The equilibrium groundwater contours generated by the calibrated model are presented on Plates 13 and 14 for the east and west plant areas, respectively. It can be seen that there is reasonable agreement with the field conditions shown on Plate 1. Although this combination of input parameters does not constitute a unique solution for the governing equations used within the model, the solution obtained utilized realistic input values, and would, therefore, be a reasonable simulation of field conditions.

SIMULATION OF DRAIN TILE SYSTEMS

After evaluating the calibrated model, the groundwater elevation was lowered at strategically located nodes which would be used to describe the drain tile collection system. The groundwater level at these nodes was fixed at a constant head equal to the drain tile invert elevation. In this way, the influence of a drain tile upon the groundwater flow regime was simulated.

For the east plant area, the drain tile collection system simulated follows DuPont Road to Adams Avenue as shown on Plate 15. Several trials were made using the constant head approach to achieve the desired drawdown. It is noted that this scheme, although not capable of creating a gradient reversal on the downgradient side of the drain tile alignment, significantly reduces the off-site flow of groundwater. To determine the required volumetric flow to obtain these contours, nodes along the tile drain alignment were simulated as pumping wells (discharge points). The resulting groundwater contours generated by this simulation are presented on Plate 16.

For the west plant area, three drain tile collection system schemes were examined to determine their effect on the modeled groundwater regime. These three schemes are presented on Plates 17, 18 and 19, respectively. After several trials, the value of constant head to obtain a gradient reversal from the river to the drain was identified. The groundwater contours for the DuPont Road scheme are presented on Plate 20. Finally, selected nodes along the locus of points used to describe the drain tile collection system were identified as discharge points to determine the required volumetric flow to obtain similar drawdown contours as those produced using the constant head approach. A detailed modeling report is in preparation and will be submitted under separate cover.

Based on the results of the west area modeling effort, all systems examined, except the Adams Avenue scheme, can achieve a drawdown sufficient to create a gradient reversal from the Niagara River. However, the alignment for the drain tile collection system along DuPont Road offers a specific advantage in that it intercepts those contaminated areas shown on Plates 3, 4 and 5, thereby reducing the contaminant flow length to the drain tile collection system. In addition, the alignment along DuPont Road also offers advantages in construction. These include a shallower depth to the top of rock, the minimal disturbance of adjacent sewer lines along DuPont Avenue and favorable top of rock contours to establish the minimal gradients of the pipe alignment required for flow. Therefore, the DuPont Road alignment is selected for further evaluation in conjunction with the cutoff wall configurations.

SIMULATION OF CUTOFF WALLS

The alternative slurry trench cutoff wall alignments were simulated by establishing relatively impermeable boundaries at appropriate locations. To achieve the relatively impermeable boundaries, the directional hydraulic conductivity values at the appropriate nodes were reduced to approximately $1x10^{-6}$ cm/sec. Each cutoff wall case for the east and west plant areas was examined in conjunction with the drain tile collection system to determine the effect on the drain tile collection system pumping rate. For both the east and west plant areas the drain tile collection system alignment along DuPont Road was selected for evaluation. The results of these modeled conditions are discussed in detail below.

Each of the nine alternatives were evaluated with respect to the volumetric pumping rate required to achieve the necessary drawdown. Table 5 presents those flow rates for each alternative. It must be noted that these flow rates are approximate. It is believed that the relative magnitudes of the flow rates are sufficient to utilize for subsequent cost comparisons.

Using the drain tile-only alternative as a base, the following general statements can be made concerning flow rates for the various alternatives:

- o Downgradient cutoff walls have a negligible impact on flow rates.
- o Upgradient cutoff walls have a significant impact on flow rates, with reduction in flow of approximately 50 percent from the east plant area and approximately 45 percent from the west plant area.
- o Circumscribing cutoff walls have the most significant impact on flow rates, with reductions of approximately 65 percent from both the east and west plant areas. Essentially all of the groundwater flow pumped for treatment under this alternate is generated by infiltration of rainfall and snow melt.

Based on these results, the downgradient cutoff wall scheme will not be considered further. In order to fully evaluate all other possible combinations of alternatives in the east and west plant areas, a 3x3 matrix was prepared which results in a listing of nine possible overall alternatives. This approach is required since nine separate flow rates requiring treatment at a central treatment facility will result. The nine combination alternatives and corresponding flow rates are presented in Table 6.

Examination of the limited potentiometric groundwater data in the B-Zone (see Plate 21) indicates that, for the cases simulated on the west plant area, an upward gradient did not result from the induced drawdown in the overburden material by the modeled drain tile collection system. This does not, however, preclude the possibility that a gradient reversal (from the B-Zone to the overburden) could occur. In the east plant area however, the data suggests that a gradient reversal could occur in the cases modeled. The actual quantity of flow from the B-Zone to the overburden would be dependent on the amount of drawdown induced by artificial means, the degree of hydraulic connection between the B-Zone and the overburden materials, and the pumping rate from the drain tile collection system. The upward flow from the B-Zone to the overburden is expected to have minimal impact upon the pumping rate established for the drain tile collection system.

WATER TREATMENT

BACKGROUND: Further screening of the alternatives described in the Phase I Remediation Studies report of April, 1984 has led to the evaluation and selection of several treatment trains likely to meet the expected requirements for treatment and disposal of groundwater pumped from the east and west plant remediation areas. Some of the key factors influencing the selection and preliminary sizing of treatment processes for cost estimation are discussed in the following paragraphs.

The levels of concentration of various contaminants can be estimated by combining data from wells located in the probable zones of influence of the groundwater collection systems. Table 7 presents a summary of concentrations of various parameters in the groundwater. These concentrations were estimated for each area and for combined flow from both areas, assuming blending in proportion to expected pumping rates. Also shown in Table 7 are estimated daily loadings at the expected flow rates. Although the flow rates from the east and west plant areas will be dependent upon several factors previously discussed, these loadings are based upon estimated pumping rates of 10 to 40 gpm from the east area and 5 to 25 gpm from the west area. Further observations from those data are:

- The probable range of TOC concentration in the west plant area will be 25 to 50 milligrams per liter, while in the east plant area TOC concentrations may range up to 200 milligrams per liter.

- Strippable compounds in the west plant area may account for 40 to 50 percent of the total TOC, but apparently a negligible portion of the TOC in the east area.

As noted from Table 7, the approximate ratio of carbon in the measured volatile compounds to the measured total organic carbon content (SUM/TOC) for the various wells for the west plant area is 1/2 and for the east plant area is 1/60. Thus, it is indicated that there are other sources of TOC in the east area of significance which are not accounted for in the measured volatile compounds.

The alternative of discharging contaminated water to the Niagara Falls municipal sewer system was not used for cost estimating because the system capacity is limited. Therefore, the alternative of sewer discharge was not further investigated. For the alternative of direct discharge of extracted/treated groundwater to the Niagara River, guidelines for treatment objectives may be adopted for the preliminary evaluation of applicable treatment processes and for order of magnitude cost estimates of applicable alternative systems. For this purpose, Table 8 summarizes effluent quality objectives used as a basis for this preliminary evaluation of treatment alternatives.

There may be limits on atmospheric volatile organic compound (VOC) emissions for operations such as air stripping. Limits will be defined in terms of specific compounds, as well as total VOC's in accordance with regulations in the New York DEC Air Guide No. 1. The Air Guide regulations contain tables of information which provide a basis for establishing emission limits for substances of different degrees of toxicity. The information on those lists was compared to the compounds in Table 3 of the Phase I Report -"Contaminants Found in A-Zone Groundwater at Concentrations Greater Than 10 ppb" and those listed as "indicator compounds" based on the results of sampling of NYDEC wells. For those compounds, the most restrictive list in the regulations for "highly toxic" compounds includes benzene, carbon tetrachloride, vinyl chloride and PCB's. The next most restrictive list (moderately toxic compounds) includes chloroform, tetrachloroethylene, trichloroethylene, BHC's, chlorobenzene, cresols, phenols, and 1,1,2,2-tetrachloroethane. Also listed in a table of "low to moderate toxicity" compounds are methylene chloride and 1,1,1-trichloroethane. Based on preliminary estimates of probable emission rates of various compounds for the expected design range of flow rates and concentrations, it is prudent to include atmospheric emission control from air stripping. Depending on final flow rates and loadings, need for air emission control may be eliminated. The design of facilities will also require the investigation for emission control from more dispersed emission sources as in storage and blending tanks or from biotreatment facilities.

ALTERNATIVE SCREENING: A number of alternative treatment/disposal technologies were described in the Phase I Remedial Studies report. Some of those were eliminated in that report as inappropriate for this case. As discussed previously in this report, soil flushing and the use of in-situ bioreclamation have been eliminated for technical reasons.

In light of the key factors mentioned previously in "Background and Project Description" and considering other screening criteria and experience factors, the alternatives for treatment and disposal have been evaluated technically to select processes and technologies that offer more attractive potential for application in the remedial plans for the Niagara Plant. The more pertinent general criteria which served as guidelines in this evaluation were:

- Processes or technologies which have been more broadly demonstrated or applied to similar treatment requirements.

- Processes which must have a high potential ability to achieve the required degree of treatment.

- Suitable equipment and processes which are commercially available in appropriate size ranges.

- Systems flexibility which allows for quantity and quality variations and for unknown factors.

- Systems which accommodate the differences in groundwater characteristics between the remediation areas.

- Simplicity of operation.

- Proposed effluent discharge loadings and characteristics which will need to be integrated with existing permits and discharges.

- Multiple units in series offer a better chance for reliable high level performance.

For the levels of TOC and specific compounds expected and for the degree of treatment needed and recognizing the general screening criteria mentioned above, the following process alternatives were found to be inappropriate:

- o Anaerobic biotreatment - this process has limited field application experience at the levels of contamination expected in this case.

- o Attached growth aerobic biotreatment - there is limited field application experience to organic chemical wastes as expected in this case.

- o Biologically activate granular activated carbon column - this is an effective process for treatment of surface waters with low levels of organic contamination. The process is not suited to treatment of waters containing higher concentration of organic materials where uncontrolled biological activity may occur. The result can be the development of anaerobic conditions, seriously upsetting the process performance and creating odor and corrosion problems.

For the purpose of preliminary evaluation of order of magnitude costs of treatment of contaminated groundwater, the aforementioned processes were not further considered for the technical reasons cited. Processes which are considered to be applicable to the treatment objectives and which meet the guidelines used in evaluation are discussed in the following paragraphs, relating them to the individual treatment objectives.

REMOVAL OF SOLIDS AND NON-AQUEOUS PHASE LIQUIDS: Hydrogeologic investigations have indicated that non-aqueous phase liquids may be present at some locations as noted previously. For those immiscible liquids, a gravity separation device is a simple means for removal of separated phases and is recommended as the most appropriate approach. The quantity and separation characteristics of such non-aqueous phase materials are not well defined at this point. However, the provision of a simple baffled gravity differential separator with the capability to withdraw a settled phase (including any suspended solids extracted by the groundwater collection system) and to allow manual skimming of floating solids affords the opportunity to remove and recover for disposal those materials in the simplest and most cost effective manner.

VOLATILE ORGANICS: As noted on Table 7, approximately half of the total organic carbon observed in wells contributing to the west remediation area is attributable to the volatile organic carbon compounds listed. Experience elsewhere has demonstrated that those compounds listed are relatively amenable to removal by air stripping or steam stripping. For the concentrations of VOC's in the collected waters, air stripping in counter-current packed columns affords a relatively simple controllable process and should be cost effective compared to steam stripping. Steam stripping can be the process of choice where concentrations of VOC's are higher and the overall required percentage removal is greater.

It should be noted that, depending on the rates of emission of specific compounds and on other site-specific factors, such as location, background levels, other sources of emission and existing air emission permit limitations, it may be necessary to provide air pollution control devices to limit the emission rate of volatile organic compounds. At the current level of investigation, it has not been confirmed that such air pollution control will be necessary. For the purpose of evaluating order of magnitude costs for treatment, it is prudent to incorporate the costs for such air pollution control. Reliable demonstrated technology for the control of organic vapor emissions in dilute air streams is the use of vapor phase activated carbon. Vapor phase carbon absorption systems can be regenerated in place with steam. The organic compounds regenerated in the steam can be condensed and recovered for disposal or reuse in a relatively concentrated form.

The application of stripping for volatile organic removal does not seem appropriate for the expected water chemistry withdrawn from the east remediation area since, as noted on Table 7, only a very small portion of the total organic carbon appears attributable to volatile compounds.

TOC REMOVAL: Both biological treatment and liquid phase activated carbon adsorption (generally fixed bed granular activated carbon), or combinations of those two processes, have been widely investigated and applied for the treatment of organic chemical wastewaters. The effectiveness of either process and the factors potentially interfering with reliable performance have been described in the Phase I Remediation Studies report. Specific studies of the water to be treated are generally recommended to establish biodegradability and kinetic parameters, and to define carbon adsorption characteristics and degree of removal. For carbon adsorption it has been amply demonstrated that low molecular weight organic compounds generally are not effectively removed by activated carbon alone. In the remediation alternatives considered in this case, many of the lower molecular weight compounds expected from the west remediation area could be removed by air stripping. Thus, granular activated carbon could be used for the removal of the non-volatile organics from that area, as well as for the extraction of total organic carbon in the east area.

The PACT process, developed by DuPont and currently licensed by Zimpro, incorporates a powdered activated carbon-enhanced biological aerobic treatment system. This process combines the features of biological treatment and carbon adsorption, offering the advantage of both removal mechanisms in a generally synergistic or additive mode. The feasibility of the PACT process depends upon:

- An adequate biodegradable fraction of organic material which supports biological growth and which results in the accumulation of the powdered carbon into the biomass.

- The fact that adsorbed organic materials do not become inhibitory and interfere with the associated growth of microrganisms with carbon.

The available data on the BOD, TOC and BOD-level toxicity for well water samples suggest that PACT treatment of the collected waters from the east area appear to be more feasible. It would be less feasible for combined collected waters from the east and west areas and likely not feasible for collected waters from the west area. Given the current lack of biodegradability and carbon adsorbability of compounds contributing to non-volatile TOC from both remediation areas, the somewhat conservative approach of applying a PACT system for the east area or for the combined areas has been taken in the development of preliminary order-of-magnitude cost estimates. The effectiveness of granular activated carbon alone, for both the east area and the air-stripped west area waters, if confirmed by supplemental investigations, would probably reduce the capital cost of treatment by eliminating the PACT alternative, although the cost of a larger GAC adsorber and annual costs for carbon would increase.

The application of multiple processes in compatible series and parallel arrangements, utilizing those considered to be most applicable as previously discussed, has been used in the development of alternatives for comparison of remediation alternative costs. Those systems which have been utilized for this order-of-magnitude cost estimate preparation are all expected to be capable of meeting the preliminary established treatment objectives. The applicability and design basis of processes and arrangements are subject to confirmation by supplemental evaluation of the treatability of the expected groundwater combinations.

TREATMENT ALTERNATIVE EVALUATION: Based on the previously described background and on the preliminary screening of treatment processes, several treatment trains were selected as representing those potentially applicable to attain the degree of treatment expected to be required for direct discharge to the Niagara River. The trains selected were not intended to represent the entire spectrum of possible treatment systems, but rather as a basis to evaluate the order-of-magnitude economics of practicable treatment alternatives. The treatment trains selected for this purpose are illustrated on Plate 22. A brief description of each alternative follows.

Alternative 1: This alternative consists of parallel separate treatment trains for the west and east remediation areas in recognition of the difference in characteristics of those two streams (especially the apparent absence of strippable compounds from the east area). The west area train includes a receiving/blending/storage tank to serve as a surge tank to balance the operation of treatment facilities with the operation of the collection system. This unit is followed by a gravity differential separator with skimming and desludging facilities (with separated non-aqueous phases going to holding/decanting facilities for off-site disposal). The effluent from the phase separator is pumped to packed tower counter-current air strippers, equipped with vapor phase activated carbon adsorbers to recover stripped organics from the exhaust air via steam regeneration of the carbon (recovered condensates are accumulated for off-site disposal). The stripped effluent is pumped to a liquid phase granular activated carbon unit for removal of non-volatile organics.

The east area train has a separate receiving and phase separation unit similar to those described for the west area. Following phase separation, the groundwater is pumped to a PACT system for biological and adsorptive removal of TOC. For the design flows expected in this case, on-site regeneration of spent powdered activated carbon and concurrent thermal destruction of excess biological sludge (as is common in larger PACT systems) is not economically feasible, so those residual streams (thickened) are accumulated for off-site disposal. To enhance removal performance, the PACT effluent is pumped to a polishing filter to reduce residual biological and carbon solids to low levels. The filter effluent from the east area treatment system is combined with the effluent from the granular activated carbon unit in the west area train for discharge to the Niagara River via an effluent monitoring station. Note that the polishing filter effluent might alternately go to the granular activated carbon unit for further adsorptive removal of TOC, if appropriate.

Alternative 2: This alternative utilizes a single train for the combined east and west area waters. A receiving, blending storage tank for both streams and a phase separator are provided as the first two units in series similar to those described for Alternative 1. The separator effluent is pumped to air strippers for removal of volatile organics (primarily from the west area). Air strippers might be eliminated from this alternative since some air stripping would occur in the aeration tanks of the PACT system. If air pollution control is required, these controls would be more difficult to accomplish for the more dispersed aeration tank off-gas than for the air stripper. The stripper effluent is pumped to a PACT system, and then to a polishing filter, and then, via a monitoring station, to the Niagara River.

Alternative 3: For this alternative, the west area treatment system is similar to Alternative 1 through the air stripper stage. The east area treatment system is similar to Alternative 1 through the phase separator. Following those stages, the streams are then combined and sent to a PACT system and polishing filter similar to that occurring in Alternative 2.

For the three basic treatment schemes (Alternatives 1, 2 and 3) previously described and shown on Plate 22, rough sizing has been performed to provide a basis for order-of-magnitude estimates for capital and O&M costs. Since flow rates from each area will vary depending on collection and containment methods, treatment costs were developed for different flow rates. Two design flow rates were used for each remediation area; 25 gpm and 50 gpm from each, giving a combined flow of 50 gpm and 100 gpm from the two areas.

The key design parameters used for cost estimation of units in the treatment trains are listed in Table 9. Order-of-magnitude cost estimates for capital (with an accuracy of ± 50 percent) and O&M costs (± 25 percent accuracy) were prepared for each alternative treatment train illustrated on Plate 22 at 25 gpm and 50 gpm flow rates, for each area. Capital costs and annual O&M costs are summarized in Tables 10 and 11, respectively. The unit cost factors used in estimating operating and maintenance costs are presented in Table 12. Note that the difference in capital costs among the alternatives at the same design flow rate is about 10 percent and the difference in O&M costs at the same flow rate is less than 10 percent. This difference is within the accuracy of estimating techniques employed. Thus, there is not a clearly indicated economic advantage to any of the alternative treatment schemes considered.

Capital and O&M costs are presented on Plates 23 and 24, respectively, as a function of the design capacity, using average costs of the three alternative trains. Also shown on these plates are dashed curves showing the variations in costs at ± 50 percent from average for capital and ± 25 percent from average for O&M costs.

Based on information available at this time, and on the preliminary evaluation of treatment alternatives, Alternative 1 has better flexibility and reliability. Bench-scaled studies are needed to supplement the judgment on which the selection is based. Specifically, the adsorption capacity and performance of granular activated carbon must be established, and the feasibility of the PACT process must be demonstrated.

To complement the description of Alternative 1, and to further illustrate the probable nature and scope of required treatment facilities, Appendix B has been prepared. It includes a Summary of Design Basis and Major Unit Sizing for Treatment Alternative 1, sized for flow rates expected from Remediation Alternative 9. Also included is a Location Plan, Plate B-1, showing the proposed location of treatment facilities and a Schematic Flow Diagram (Plate B-2). The estimated area requirements for the facilities described are approximately 10,000 square feet.

COST EFFECTIVENESS AND PERFORMANCE ANALYSES

Because of the preliminary screening process, only those alternative technologies which are both technically sound and environmentally effective were considered as part of this cost effectiveness analysis. The nine alternatives examined for cost (Tables 6 and 13) meet the stated objective of remediation: minimization of off-site migration of contamination in the overburden. Therefore, all alternatives are considered environmentally effective and this criterion is not primary in the selection of the most cost effective alternative. It follows that a cost comparison is the primary analysis to be performed. Subsequently, for those alternatives which are the least expensive, other environmental factors will be considered as part of the final alternative selection process.

Cost estimates were prepared for each alternative based on capital and operation and maintenance costs. Presented in Table 13 are costs for the nine alternatives subdivided into the following categories: hydraulic controls, physical barriers, and wastewater treatment. The following major items were considered for costing purposes:

- o The use of a drain tile system for control of the overburden groundwater regime would be located as shown on Plates 15, 17, 18 and 19 for both the west and east plant areas.

- o The groundwater from the drain tile collection system would be collected in stratigically located wet wells and pumped to a central treatment facility.

- Disposal of the limited materials excavated for the drain tile collection system and pressure return lines deemed unsuitable for use as backfill results in neglible cost impact.

- Dewatering pumpage would be returned to the groundwater flow regime without treatment.

- The slurry trench cutoff walls for the various cases costed are presented on Plates 7-10.

- The depth of the cutoff wall was based on the overburden isopach contours presented on Plate 12.

- A premium cost was assigned to those sections of the slurry trench cutoff wall that traversed the shot rock zones shown on Plate 6.

- The probable range of TOC concentration requiring treatment would be between 25 and 50 mg/l in the west plant area and up to 200 mg/l in the east plant area (see Plate 5).

- Strippable compounds in the west plant area may account for up to 50% of the total TOC. A much smaller percentage of strippable compounds (less than 10 percent) appear to be present in the east plant area.

- Combinations of air stripping with biotreatment or granular activated carbon adsorption (PACT process) are considered for costing. Suspended solids and heavy and non-aqueous phase liquids are separated by physical separation techniques, such as gravity settling.

As can be seen in Table 13, alternatives 5, 6, 8, and 9 are more cost effective than the others. These alternatives are most effective in reducing flow rates and thus, reducing treatment costs. It is noted that, if treatment costs have been underestimated, then these low flow alternatives would become even more cost effective.

In addition, because costs related to cutoff walls or drain tiles are relatively low as compared to treatment costs, larger costs associated with these functions would not significantly impact the relative cost effectiveness of these alternatives. Table 14, which shows the alternative costs broken down into lump sum treatment versus all costs other than treatment costs illustrates that increasing the non-treatment costs by 50% does not substantially alter the relative cost effectiveness of the alternatives.

To select the preferred alternative, an evaluation of the advantages and disadvantages associated with the four most cost effective alternatives is useful. The following criteria has been identified as applicable in evaluating the alternatives: (1) dependability in the event of shut-down of hydraulic controls, and (2) effectiveness of controlling off site migration of contaminants.

In the event of temporary shut-down of the hydraulic controls system, the most effective alternatives involve those with cutoff walls completely surrounding the site. These barriers would effectively contain off-site contaminant migration in the absence of hydraulic controls.

Cutoff walls surrounding the entire site are more effective in controlling off-site contaminant migration than the up-gradient cutoff walls only, because of the presence of a down-gradient physical barrier. In addition, it is noted that, because of the relatively steep groundwater gradients toward the northeast in the east plant area, hydraulic controls in this region will not be fully effective in containing the contamination which is currently north of Adams Avenue as shown on Plate 5. The cutoff wall surrounding the east plant area, however, would be more effective in containing this contamination.

RECOMMENDED REMEDIATION CONCEPT

The Phase II Remediation Studies were conducted in order to further evaluate the most effective alternatives for the remediation of the Niagara Plant site. Based upon the alternatives analysis and the associated costs, it is concluded that alternatives which involve a minimum pumping through increased use of vertical barriers to horizontal groundwater flow result in the most cost effective remedial solution. Hence, it is concluded that the use of a drain tile collection system in conjunction with a circumscribing slurry trench cutoff wall as shown on Plate 25 would result in the most cost and environmentally effective alternative for remediation of the Niagara Plant site. In addition, should the treatment cost data (capital and O&M) utilized in these analyses be underestimated, the cost advantage of a slurry trench cutoff wall to impede flow would be greater.

Consistent with the conclusion that a drain tile collection system installed in the overburden in conjunction with a circumscribing slurry trench cutoff wall is the preferred remedial technique, it must be noted that groundwater requiring treatment would be derived from three major sources. These sources are presented in descending order of importance.

- o infiltration of precipitation
- o flow through the cutoff wall
  - seepage flow
  - flow through discontinuities in the cutoff wall
- o upward migration of groundwater from the B-Zone to the overburden material.

Hence, it is concluded that as additional plant expansion occurs with the result of a reduction of infiltration, treatment cost would be further reduced. It is recommended, therefore, for final design studies, investigations should be undertaken regarding the cost effectiveness of reducing the infiltration recharge area.

IMPLEMENTATION OF REMEDIAL CONCEPT

If the recommended remedial concept is to be implemented, certain activities will need to be undertaken. These activities are necessary to develop the remedial concept to a point where a preliminary design can be prepared. These actions are briefly discussed below.

Groundwater flow conditions in the northern portion of the west plant area along Buffalo Avenue need to be further evaluated. The information for this evaluation may be available from on-going studies. If additional work is needed, it will be recommended at that time. Specifically, groundwater movement in the vicinity of the Buffalo Avenue sewer needs to be quantified. Monitoring well 20A, immediately adjacent to this sewer, as well as one of the excavations made during the manmade passageway study (utility well 3), indicates that the groundwater table is depressed in this area.

If, in fact, the Buffalo Avenue sewer is functioning as a groundwater sink, groundwater movement in the overburden into the plant site area may already be limited and implementation of the concept recommended in this report might be possible without the installation of an upgradient cutoff wall for the west plant area. This condition would not change the recommendation of the remedial concept, but the details with respect to the implementation of the concept would have to be modified to accommodate these field conditions. For the purposes of preparing this remedial concept report, it is most appropriate that the "worst case" groundwater flow conditions be used to identify the recommended remedial concept. Thus, under these conditions it is more likely that implementation of the recommended concept could occur with a decreased level of effort rather than an increased amount of work.

Treatment costs are an important factor in overall economics of site remediation. Furthermore, reliable effluent quality from all alternatives is essential. Therefore, supplemental investigations are recommended as part of the implementation of the preferred alternative. Those studies would include:

- o Evaluation of the need for air emission control from air strippers (and/or aeration or storage facilities).

- o Bench-scale evaluation of the effectiveness of, and design factors for, the application of liquid phase granular activated carbon treatment through development of adsorption isotherms and carbon column performance..

- o Bench-scale evaluation of the biomass and carbon compatibility and kinetic design parameters for the application of the PACT process through separate biological treatment followed by adsorption isotherms on the treated effluent and through operation of a bench-scale PACT unit.

Therefore, it is recommended that remedial concepts presented in this report be reviewed and a decision made as to implementation prior to the development of the detailed information needed to formulate the preliminary and, subsequently, final design of the system.

SUMMARY OF RECOMMENDED REMEDIATION CONCEPTS

WEST PLANT MAINTENANCE AREA

At this time, it is recommended that the west plant maintenance area be treated with a surface sealing technique in conjunction with modifying the surface contours to accommodate drainage and collection of runoff. Utilizing bituminous pavement or other low permeability sealers would effectively minimize further leaching of contaminants into the soil. Additionally, diversion ditches and catch basins would inhibit infiltration of surface runoff.

WEST PLANT AREA

For the west plant area, it is recommended that a slurry trench cutoff wall be installed to effectively circumscribe the west plant area as shown on Plate 25. In conjunction with the cutoff wall, a drain tile collection system should be installed along DuPont Road from Gill Creek to Chemical Road, north on Chemical Road between DuPont Road and Adams Avenue, and west along Adams Avenue, with a wet well at the intersection of Chemical Road and DuPont Road as shown on Plate 25. The groundwater contours, for the conceptual remediation program, are shown on Plate 26.

EAST PLANT AREA

The preferred remedial technique for the east plant area is similar to that for the west plant area. That is, a slurry trench cutoff wall should be installed to circumscribe the east plant area as shown on Plate 25. In conjunction with this slurry wall, a drain tile collection system should be installed along DuPont Road and Adams Avenue, as shown on Plate 25, with a wet well near the intersection of Hyde Park Boulevard and Adams Avenue. The groundwater contours, for the conceptual remediation program, are shown on Plate 26. Additional details regarding the drain tile collection system and slurry trench cutoff wall are presented in Appendix C.

LIMITATIONS

The findings and conclusions presented in this report are based on interpretations developed from the geologic, subsurface and groundwater data of the aforementioned reports. These findings and conclusions are subject to confirmation and revision as additional information becomes available. The recommendations presented in this report are based on the assumption that the simulated model conditions are representative of those that would exist should the recommended groundwater control scheme be implemented. The assumptions made and the variability of the basic parameters influencing the Prickett-Lonnquist model, along with the nonuniqueness of the solution presented, have been discussed in this report.

Tables

TABLE 1
REMEDIATION TECHNIQUE VS TREATMENT AREA MATRIX

Techniques	Remediation Areas in Order of Priority				
	B-81-84	B-403	West Plant Maintenance Area	B-44	HCN Incinerator
Excavation & Disposal	Area too large many buildings	Area too large many buildings	Practical	Determine Conc. Center	Determine Conc. Center
Flushing	Practical	Possible	Not Applicable	Possible	Possible
Active Containment Techniques	Practical	Practical	Not Applicable	Possible	Possible
Passive Containment Techniques	Possible	Possible	Practical	Possible	Possible
Conventional Treatment of Groundwater	Practical	Practical	Not Applicable	Possible	Possible
Bioreclamation of Contaminated Groundwater	Possible	Possible	Not Applicable	Possible	Possible

TABLE 2
LIST OF MODELED SCHEMES

EAST PLANT AREA

1e. Drain tile only.
2e. Drain tile in 1e above with downgradient cutoff wall along Adams Avenue.
3e. Drain tile in 1e above with downgradient cutoff wall along Buffalo Avenue.
4e. Drain tile in 1e with upgradient cutoff wall along Niagara Parkway.
5e. Drain tile in 1e above with circumscribing cutoff wall.

WEST PLANT AREA

1w. Drain tile only.
2w. Drain tile 1w with downgradient cutoff wall along Niagara Parkway.
3w. Drain tile in 1w with upgradient cutoff wall along Buffalo Avenue.
4w. Drain tile in 1w with circumscribing cutoff wall.

Table 3
Dupont - Niagara Plant Drawings

Drawing No.		Description	
		-Layout Plans-	
EE-20-2765	-	General Facilities Layout Plan	
EE-40-6388	-	General Facilities Layout Plan	
EE-40-6392	-	General Facilities Layout Plan	
EE-40-6422	-	General Facilities Layout Plan	
PA7-13G-117	-	Niagara Parkway Plan & Profile	
		-Pollution Facilities-	
EE-40-5295	-	Arrangement underground pressure pipes	
		-Sewerage System-	
EE-40-344	-	Sewerage Systems Dupont to Chemical Road	
NF-16212	-	Arrangement and Details 12" acid proof sewer	
NF16454	-	Plan Profile - Details 10" acid proof sewer	
NF16455	-	Plan profile, details 10" acid proof sewer	
NF17540	-	Arrangement and Details 18" acid proof sewer 24" acid proof sewer	
NF20950	-	Arrangement and Details - Dupont Road MH 100 to 101 12" acid proof sanitary	
		-Sewers: Storm and Sanitary-	
EE-40-2802	-	Northwest Plant area	Sheet 1
EE-40-2802	-	Northeast Plant area	Sheet 2
EE-40-2802	-	West Plant South of Adams Avenue	Sheet 3
EE-40-2802	-	East Plant South of Adams Avenue	Sheet 4
EE-40-2802	-	East Plant East area	Sheet 5

Table 3
DuPont - Niagara Plant Drawings
(cont'd)

EE-40-2802	-	Southwest Plant area	Sheet 6
EE-40-2802	-	West Plant South of Riversdale Avenue	Sheet 7
EE-40-2802	-	West Plant South of Adams Avenue	Sheet 8
EE-40-2802	-	Northwest Plant area	Sheet 9

-Sanitary, Storm, Cooling Tower Sewers-

W90966	-	Plan and Details

Table 4
Hydraulic Conductivity, A-Wells[1]
DuPont Niagara Plant
Niagara Falls, New York

Well No.	Hydraulic Conductivity[2] Confined	Unconfined
1A	—	$8x10^{-3}$
2A	—	$3x10^{-2}$
3A	—	$1x10^{-2}$
4A	—	$3x10^{-2}$
5A	$4x10^{-2}$	$2x10^{-2}$
6A	$6x10^{-2}$	$4x10^{-2}$
7A	$1x10^{-3}$	—
8A	$1x10^{-3}$	—
9A	—	$2x10^{-2}$
10A	—	$4x10^{-2}$
13A	$1x10^{-2}$	—
14A	$3x10^{-3}$	—
15A	—	$1x10^{-3}$
16A	$1x10^{-2}$	$3x10^{-3}$
18A	$6x10^{-3}$ (early)[3]	$6x10^{-3}$ (late)[4]
19A	$4x10^{-3}$	—
21A	$4x10^{-2}$ (early)	$1x10^{-3}$ (late)

(1) Hydraulic Conductivity test performed using the slug test method
(2) Test results in centimeters per second
(3) Hydraulic Conductivity calculated using data from early part of test
(4) Hydraulic Conductivity calculated using data from late part of test

TABLE 5
FLOWS FOR MODELED SCHEMES

EAST PLANT AREA

Scheme No.	Flow Rate (gpm)	Description
1e	30-40	Hydraulic controls only
2e	30-40	Downgrdient cutoff wall with hydraulic control
3e	30-40	Downgradient wall with hydraulic control
4e	15-20	Upgradient cutoff wall with hydraulic control
5e	10-15	Circumscribing cutoff wall with hydraulic control

WEST PLANT AREA

Scheme No.	Flow Rate (gpm)	Description
1w	20-25	Hydraulic control only
2w	20-25	Downgradient cutoff wall with hydraulic control
3w	10-15	Upgradient cutoff wall with hydraulic control
4w	5-10	Circumscribing cutoff wall with hydraulic control

TABLE 6
FLOW SUMMARY

ALTERNATIVE	DESCRIPTION	FLOW RATE DESIGNATION	(gpm)
1	Hydraulic Control only West Hydraulic Control only East	(W1 E1)	60
2	Hydraulic Control only West Upgradient Cutoff wall w/ Hydraulic Control East	(W1 E2)	40
3	Hydraulic Control only West Circumscribing cut off wall w/ Hydraulic Control East	(W1 E3)	35
4	Upgradient Cutoff wall w/ Hydraulic Control West Hydraulic Control only East	(W2 E1)	50
5	Upgradient Cutoff Wall w/ Hydraulic Control West Upgradient Cutoff Wall w/ Hydraulic Control East	(W2 E2)	30
6	Upgradient Cutoff Wall w/ Hydraulic Control West Circumscribing Cutoff Wall w/ Hydraulic Control East	(W2 E3)	25
7	Circumscribing Cutoff Wall w/ Hydraulic Control West Hydraulic Control only East	(W3 E1)	45
8	Circumscribing Cutoff Wall w/ Hydraulic Control West Upgradient Cutoff Wall w/ Hydraulic Control East	(W3 E2)	25
9	Circumscribing Cutoff Wall w/Hydraulic Control West Circumscribing Cutoff Wall w/ Hydraulic Control East	(W3 E3)	20

W = West, E = East
1. Hydraulic Control Only
2. Upgradient Cutoff Wall with Hydraulic Control
3. Circumscribing Cutoff Wall with Hydraulic Control

Table 7
Summary of Estimated Characteristics of Groundwater Pumped from West and East Remediation Areas

Indicator Parameter	Estimated Concentration - MG/L				
	West Area		East Area		Combined Weighted
	Average	Range	Average	Range	Average
TECE	23.0	4-60	1.4	<1-10	8.6
DCE	20.0	1-60	8.3	<1-30	12.2
TCE	37.0	<1-200	0.7	< 1-3	12.8
VC	1.2	< 1-10	0.9	0-1	1.0
TECEA	5.0	< 1-40	—	—	1.7
CF	86.0	<1-600	—	—	28.7
MC	14.0	<1-200	—	—	4.7
SUM	20.0	—	3.0	—	8.7
TOC	40.0	—	174.0	—	129.0

	Estimated Range of Loadings - LBS/DAY				
SUM (1)(2)	1.2-6.0	—	0.4-1.6	—	1.6-7.6
TOC (1)(2)	2.4-12.0	—	21.0-84.0	—	23.4-96.0

(1) Based on 5 and 25 gpm pumping rate from West area.

(2) Based on 10 and 40 gpm pumping rate from East area.

The volatile organics of interest (also called "indicator" organics) are:

Chloroform (CF-$CHCl_3$)

Trans 1,2-dichlorethylene (DCE - $C_2H_2Cl_2$)

Methylene Chloride (MC - CH_2Cl_2)

1,1,2,2 - Tetrachlorethane (TECEA - $C_2H_2Cl_4$)

Tetrachloroethylene (TECE - C_2Cl_4)

Trichloroethylene (TCE - C_2HCl_3)

Vinyl Chloride (VC - C_2H_3Cl)

$$SUM = f_1CF + f_2DCE + F_3MC + f_4TECEA + f_5TECE + f_6TCE + f_7 VC + f_8B + f_9CB$$

where f_1 is the fraction of carbon in CF, f_2 is the fraction of carbon in DCE, and so on.

TOC = Total organic carbon

Table 8
Preliminary Treatment Objectives
For Direct Discharge

A. BAT [2] Daily Concentration Limitations For Some Specific Compounds

Compound	Daily Concentration Limit (μg/l) [1]
DCE	125
TCE	75
VC	50
CF	75
MCL	50
Phenol	50
Cyanide	50

B. Total Daily Loading (assumed) 10 lbs/day as TOC

1) Final selection should incorporate integration with existing SPDES permit limits, location of treatment facilities and other site-specific factors.

2) From EPA "Development Document for Effluent Limitations Guidelines and Standards (Proposed) for the Organic Chemicals and Plastics and Synthetic Fibers Point Source Category, Volume II" (EPA 440/1-83009b), Tables I-1 and I-2. New York State DEC guidelines may be more stringent.

Table 9
Summary of Key Parameters
Used to Size Treatment Units
for Order-of-Magnitude Cost Estimates

Treatment Unit	Key Parameter(s)
A - Blend/Mix/Store	1. Storage Volume - 24 hrs. 2. Mixing - 0.25 HP/M gal
B - Phase Separator	1. Overflow Rate - 800 gal/ft/day 2. Mechanism/Ancillaries - Scraper Skimmer, Sludge and Scum Sumps and Pumps.
C - Air Stripper(s)	1. Performance Objective-achieve 75 μ g/1CF(1) in effluent. 2. Type - packed tower, forced draft. 3. Ancillaries - Vapor-Phase activated carbon adsorber for off-gas (air), steam regeneration on-site with plant steam, off-site disposal of recovered organics.
D - Granular Activated Carbon Adsorber	1. Carbon Capacity - 0.1 lb TOC/lb C(2) 2. Empty-bed displacement time - 30 minutes. 3. Spent Carbon - off-site regeneration or disposal. 4. Skid-mounted "package" unit(s).
E - PACT System	1. Performance Objective - <10 lbs/day TOC(3) in effluent. 2. Off-site disposal of liquid excess bio sludge and spent carbon. 3. Skid-mounted "package" system for small capacity (<50 gpm), field-erected for larger capacity.
F - Polishing Filter	1. Dual-media pressure filter. 2. Hydraulic loading - < 3gpm/ft^2. 3. Dual-unit "package" system. 4. Backwash recycle to Unit E.

(1) CF - Chloroform
(2) C - Carbon
(3) TOC - Total Organic Carbon

Table 10
Summary of Capital Costs

Item	Alternatives: 1* (50 gpm)	1* (130 gpm)	2 (50 gpm)	2 (100 gpm)	3 (50 gpm)	3 (100 gpm)
A – Mix/Blend Store	$ 128,000	$ 192,000	$ 96,000	$ 144,000	$ 128,000	$ 192,000
B. Phase Separation	300,000	400,000	200,000	250,000	300,000	400,000
C. Stripper System	116,000	200,000	200,000	212,000	200,000	212,000
D. GAC (liquid phase)	123,000	123,000	—	—	—	—
E. PACT System	320,000	380,000	380,000	520,000	380,000	520,000
F. Effluent Filter	150,000	150,000	150,000	200,000	150,000	200,000
Sub Total	1,137,000	1,445,000	1,026,000	1,326,000	1,158,000	1,524,000
Yard Piping, Electrical, Instruments, Sitework	796,000	1,012,000	769,000	995,000	812,000	1,067,000
Engineering & Contingency	600,000	762,000	558,000	728,000	610,000	804,000
TOTAL	$ 2,533,000	$ 3,219,000	$ 2,353,000	$ 3,049,000	$ 2,580,000	$ 3,395,000
Approx. Unit Cost per gal/day Capacity	$ 35.0	$ 22.4	$ 32.6	21.1	$ 35.9	$ 23.6

Refer to Plate 21 for schematics of alternative treatment trains.

* recommended alternative

Table 11
Summary of Estimated Annual O & M Costs

Item (2)	Alternative (1)					
	1 (50 gpm)	1 (100 gpm)	2 (50 gpm)	2 (100 gpm)	3 (50 gpm)	3 (100 gpm)
Operating Labor	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000
Maintenance Labor & Materials	77,000	98,000	72,000	93,000	79,000	104,000
Electric Power	12,000	19,000	13,000	32,000	16,000	29,000
Carbon Usage	37,000	74,000	30,000	60,000	30,000	60,000
Concentrated Residues & Sludge Disposal	42,000	84,000	58,000	116,000	57,000	114,000
Steam	4,000	8,000	8,000	16,000	4,000	8,000
Analytical Costs	130,000	130,000	130,000	130,000	130,000	130,000
TOTAL	$ 482,000	$ 593,000	$ 491,000	$ 627,000	$ 496,000	$ 625,000
Approx. Unit Cost	1.83 ¢/gal	1.13 ¢/gal	1.87 ¢/gal	1.19 ¢/gal	1.89 ¢/gal	1.19 ¢/gal

1) Refer to Plate 22 for schematics of alternative treatment trains.
2) Refer to Table 12 for unit costs used in estimate.

TABLE 12
UNIT COST FACTORS USED IN
ESTIMATING ANNUAL OPERATION & MAINTENANCE COSTS

1. Operating Labor

   a) Operators $20/hr
   b) Helpers $15/hr
   c) Supervisors $25/hr

2. Maintenance Labor and Materials

   4% of Estimated Capital Costs

3. Electric Power

   $0.08/kilowatt-hour

4. Carbon Usage

   $1.00 per pound (make-up or off-site regeneration)

5. Concentrated Residue and Sludge Disposal

   $0.10 per gallon

6. Steam (from existing plant supply)

   $10 per 1,000 lbs.

7. Analytical Costs

   650 samples per year at $200 per sample

Table 13
Cost Summary

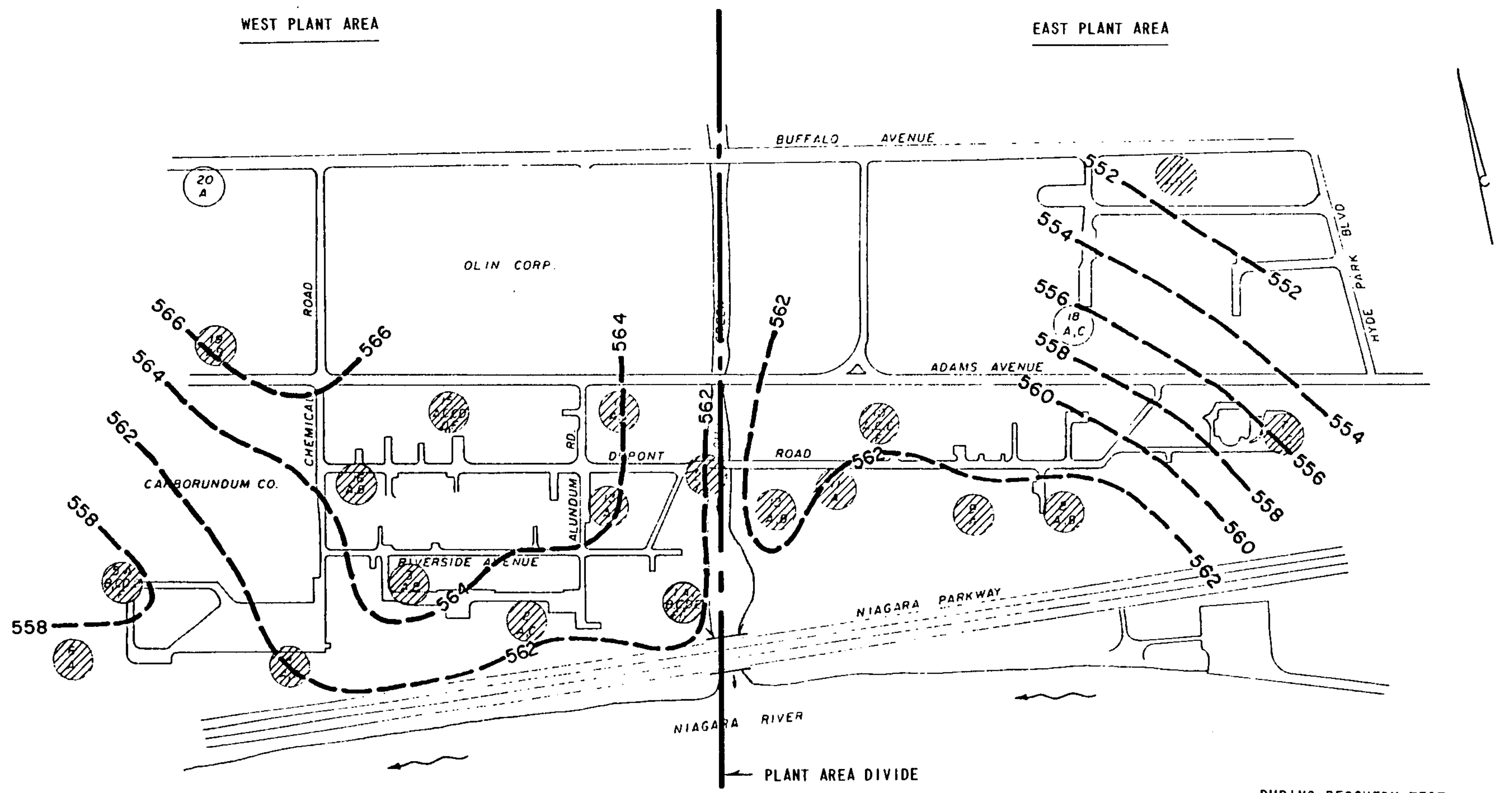
Alternative	Average Flow Rate (gpm)	Capital Costs ($1000's) Hydraulic Controls	Cutoff Wall	Water Treatment	Engineering	Total	Annual & O&M Costs ($1000's) Hydraulic Controls	Water Treatment	Total	Present Worth, O&M Costs	Total Costs
1. W1 E1	60	251	—	2,650	435	3,336	17	523	540	3,600	6,936
2. W1 E2	40	251	345	2,280	431	3,307	17	464	481	3,207	6,514
3. W1 E3	35	251	579	2,200	455	3,485	17	445	462	3,080	6,565
4. W2 E1	50	251	92	2,480	423	3,246	17	495	512	3,413	6,659
5. W2 E2	30	251	437	2,050	411	3,149	17	425	442	2,947	6,096
6. W2 E3	25	251	671	1,930	428	3,280	17	402	419	2,793	6,073
7. W3 E1	45	251	275	2,350	431	3,307	17	480	497	3,313	6,620
8. W3 E2	25	251	620	1,870	411	3,152	17	402	419	2,793	5,945
9. W3 E3	20	251	854	1,750	428	3,283	17	376	393	2,620	5,903

W = West, E = East
1. Hydraulic Control Only
2. Upgradient Cutoff Wall with Hydraulic Control
3. Circumscribing Cutoff Wall with Hydraulic Control

Table 14
Sensitivity of Cost Effectiveness Analysis to Increases in Non-Treatment Costs

	Base Costs			Increase Non-Treatment Costs by 50%	
Alternative	Treatment Costs	Non-Treatment Costs	Total	Non-Treatment Costs	Total
W1 E1	6,088	401	6,489	602	6,690
W1 E2	5,275	799	6,074	1,199	6,474
W1 E3	5,097	1,068	6,165	1,602	6,699
W2 E1	5,712	507	6,219	761	6,473
W2 E2	4,771	905	5,676	1,358	6,129
W2 E3	4,526	1,174	5,700	1,761	6,287
W3 E1	5,423	717	6,140	1,076	6,499
W3 E2	4,371	1,115	5,485	1,673	6,044
W3 E3	4,113	1,383	5,496	2,075	6,188

Plates



DURING RECOVERY TEST

OCTOBER 17, 1983, TIME ~ 1200

LEGEND:

WELL CLUSTER NUMBER (NO.)
WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

561 GROUNDWATER ELEVATION

NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM THAT SHOWN.

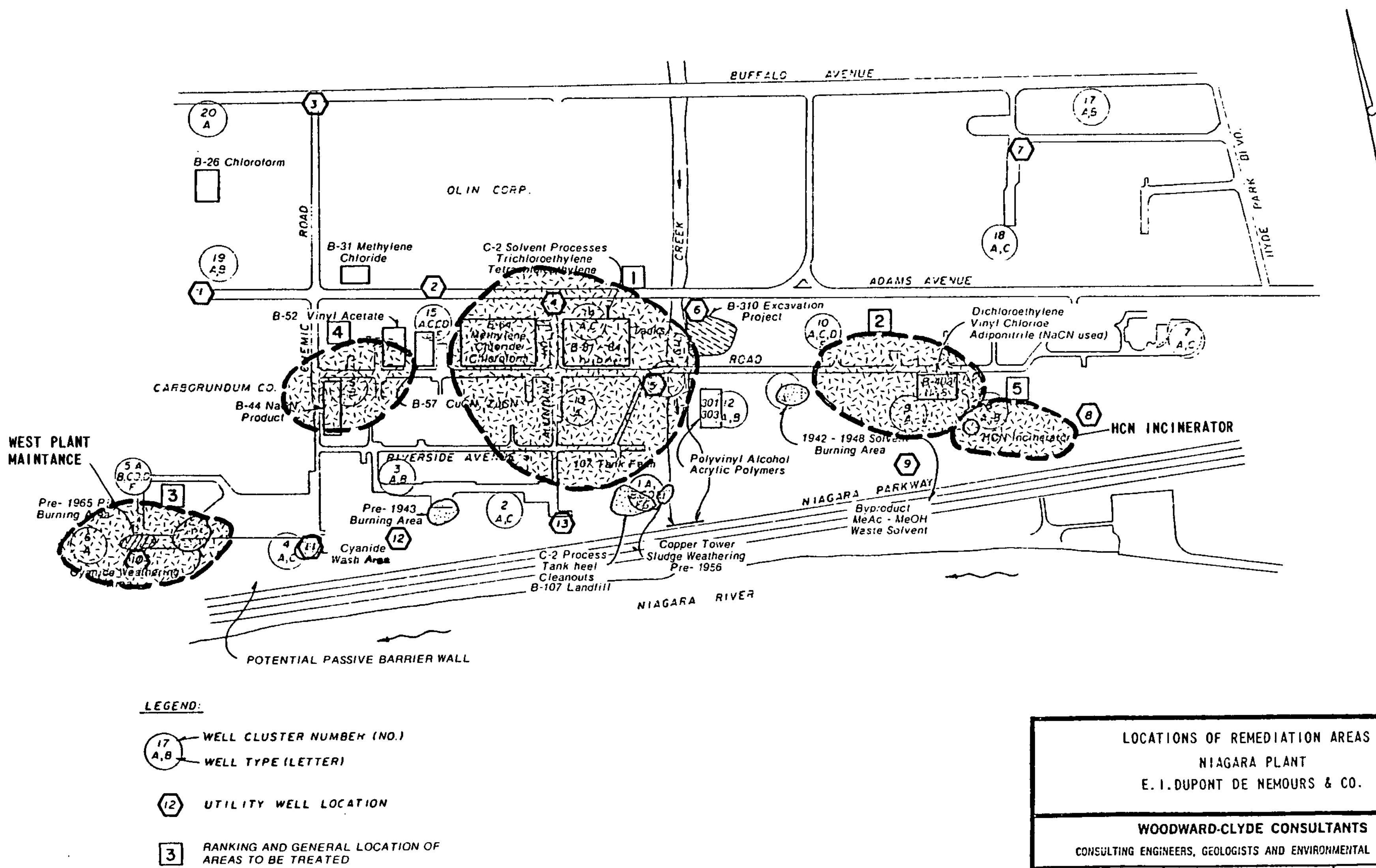
A-ZONE GROUNDWATER CONTOURS
INITIAL CONDITIONS
NIAGARA PLANT SITE
E. I. DUPONT DE NEMOURS & CO., INC.

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: D.W.B.	SCALE IN FEET 0 300	DATE: 6/18/84
CHECKED: C.R.C.		JOB: 83C2236-8

PLATE 1

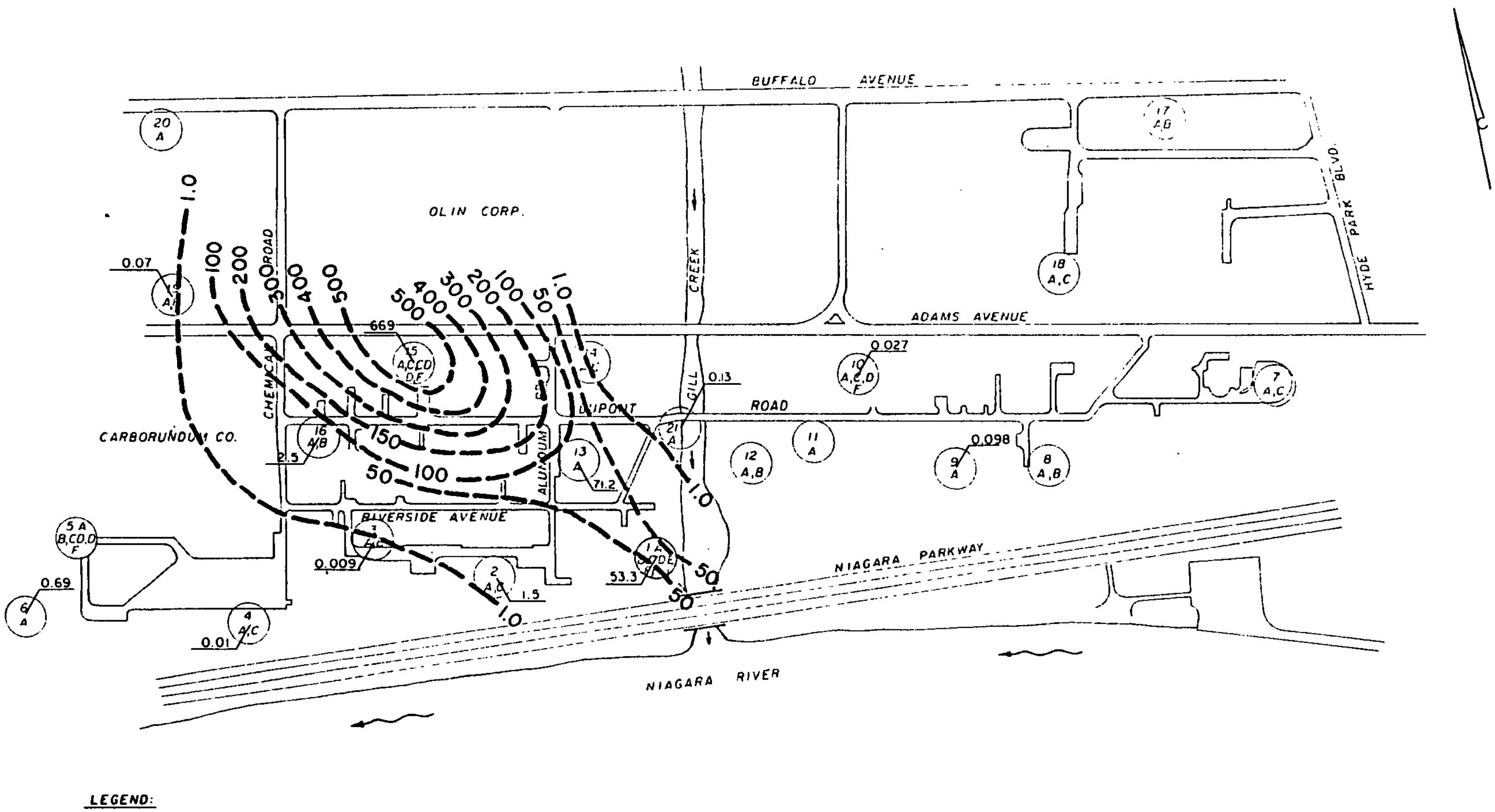


LOCATIONS OF REMEDIATION AREAS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: D.W.B.	SCALE in FEET	DATE: 6/18/84	
CHECKED : C.R.C.	0 300	JOB : 83C2236-8	

PLATE 2



CONTOUR INTERVAL AS NOTED
CONCENTRATIONS IN PPM (mg/l)

NOTE: CONCENTRATION CONTOURS HAVE BEEN INTERPOLATED TO ILLUSTRATE AREAS OF RELATIVE CONTAMINATION AND ARE NOT INTENDED TO REPRESENT ACTUAL GROUNDWATER QUALITY CONDITIONS.

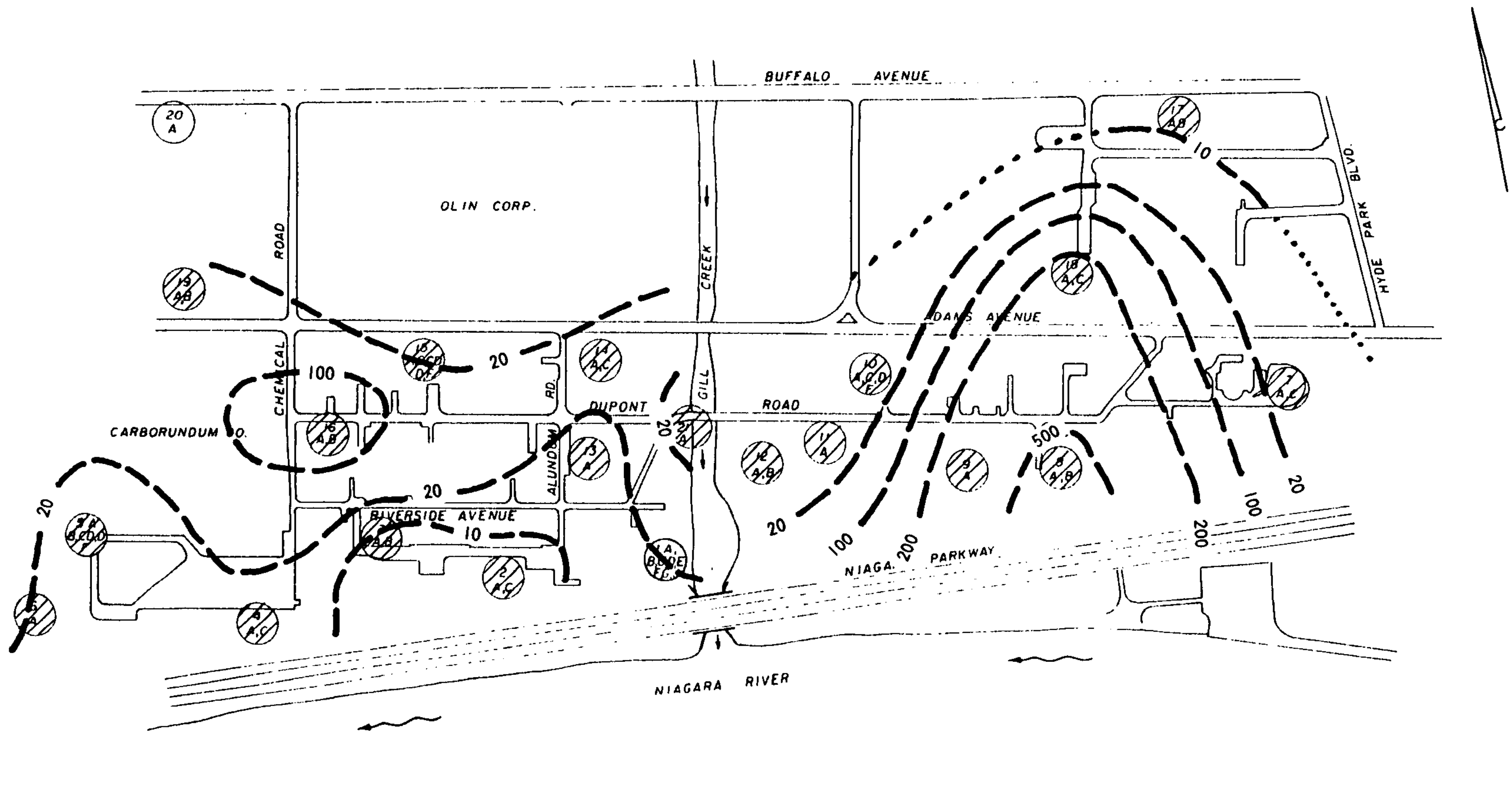
APPARENT CONCENTRATION CONTOURS FOR
C-1 COMPOUNDS - OCTOBER SAMPLING -"A" WELLS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: D.W.B.	SCALE in FEET		DATE: 6/18/84
CHECKED : C.R.C.	0	300	JOB : 83C2236-8

PLATE 3



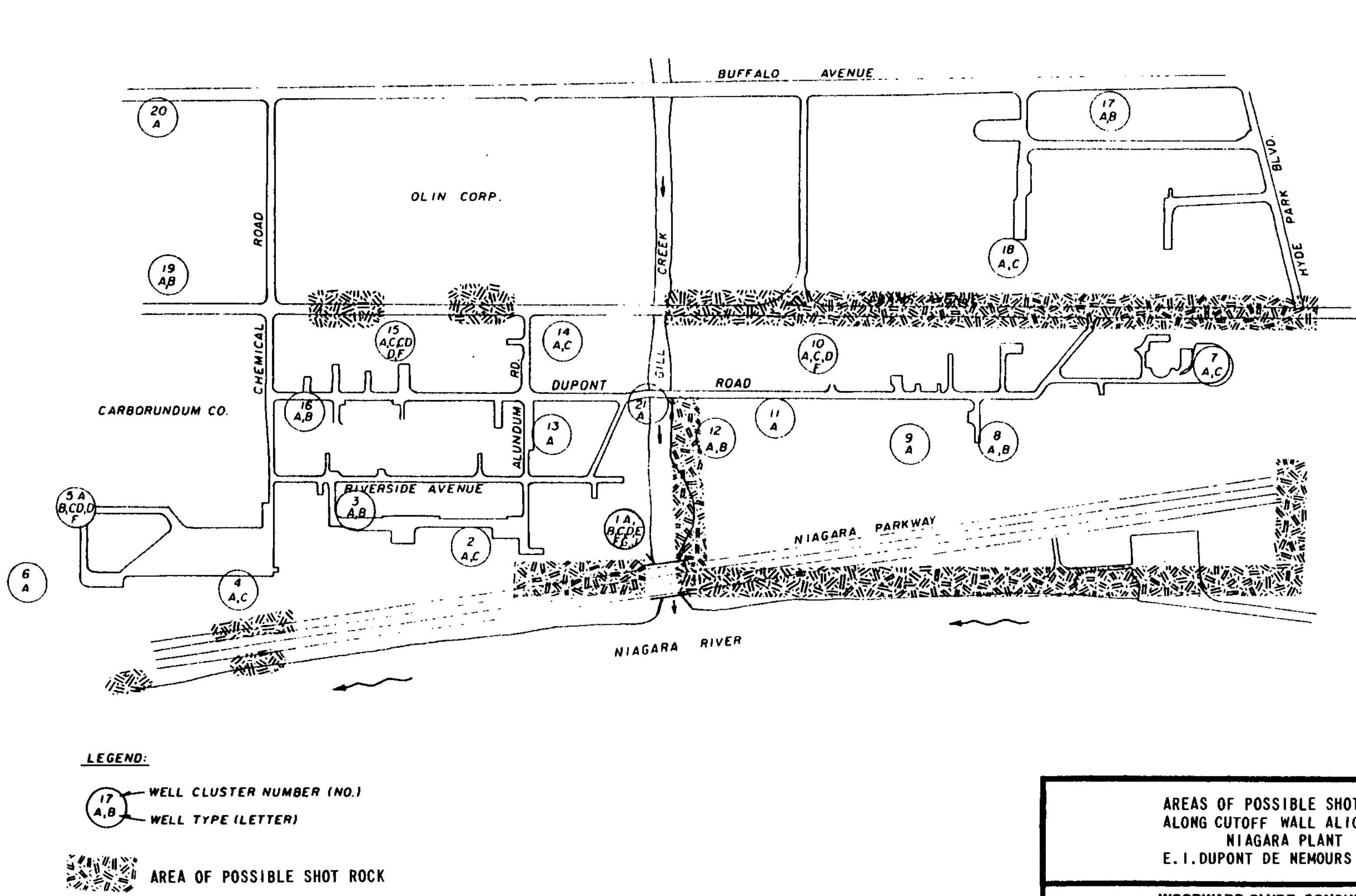
LEGEND:

WELL CLUSTER NUMBER (NO.)
WELL TYPE (LETTER)
WELLS USED TO GENERATE CONTOURS
20 TOC CONTOUR IN PPM

NOTE: AVERAGE CONCENTRATIONS IN MG/L FOR THREE MONTHS DATA EXCEPT WELLS 1 AND 21 (FOR FOUR MONTHS DATA)

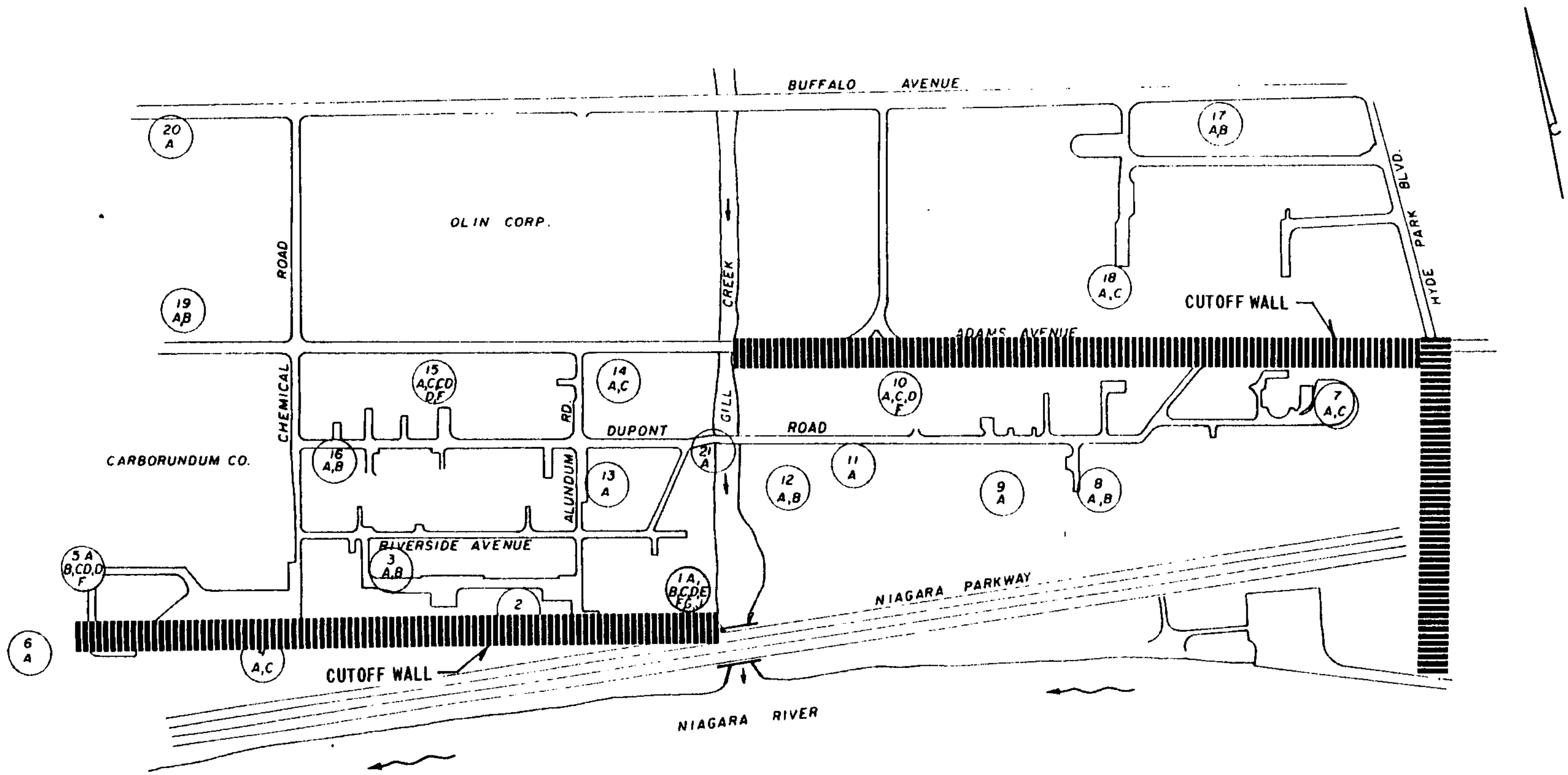
APPARENT TOC CONCENTRATION CONTOUR MAP A-ZONE NIAGARA PLANT E.I.DUPONT DE NEMOURS & CO.			
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS			
DRAWN BY: D.W.B.	SCALE IN FEET 0 300	DATE: 6/18/84	
CHECKED: C.R.C.		JOB: 83C2236-8	

PLATE 5



AREAS OF POSSIBLE SHOT ROCK ALONG CUTOFF WALL ALIGNMENTS NIAGARA PLANT E. I. DUPONT DE NEMOURS & CO.		
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS		
DRAWN BY: D.W.B.	SCALE in FEET 0 300	DATE: 6/27/84
CHECKED: C.R.C.		JOB: 83C2236-8

PLATE 6



LEGEND:

(17 A,B) — WELL CLUSTER NUMBER (NO.) — WELL TYPE (LETTER)

CUTOFF WALL - APPROXIMATE PERMEABILITY 10^{-6} cm/sec

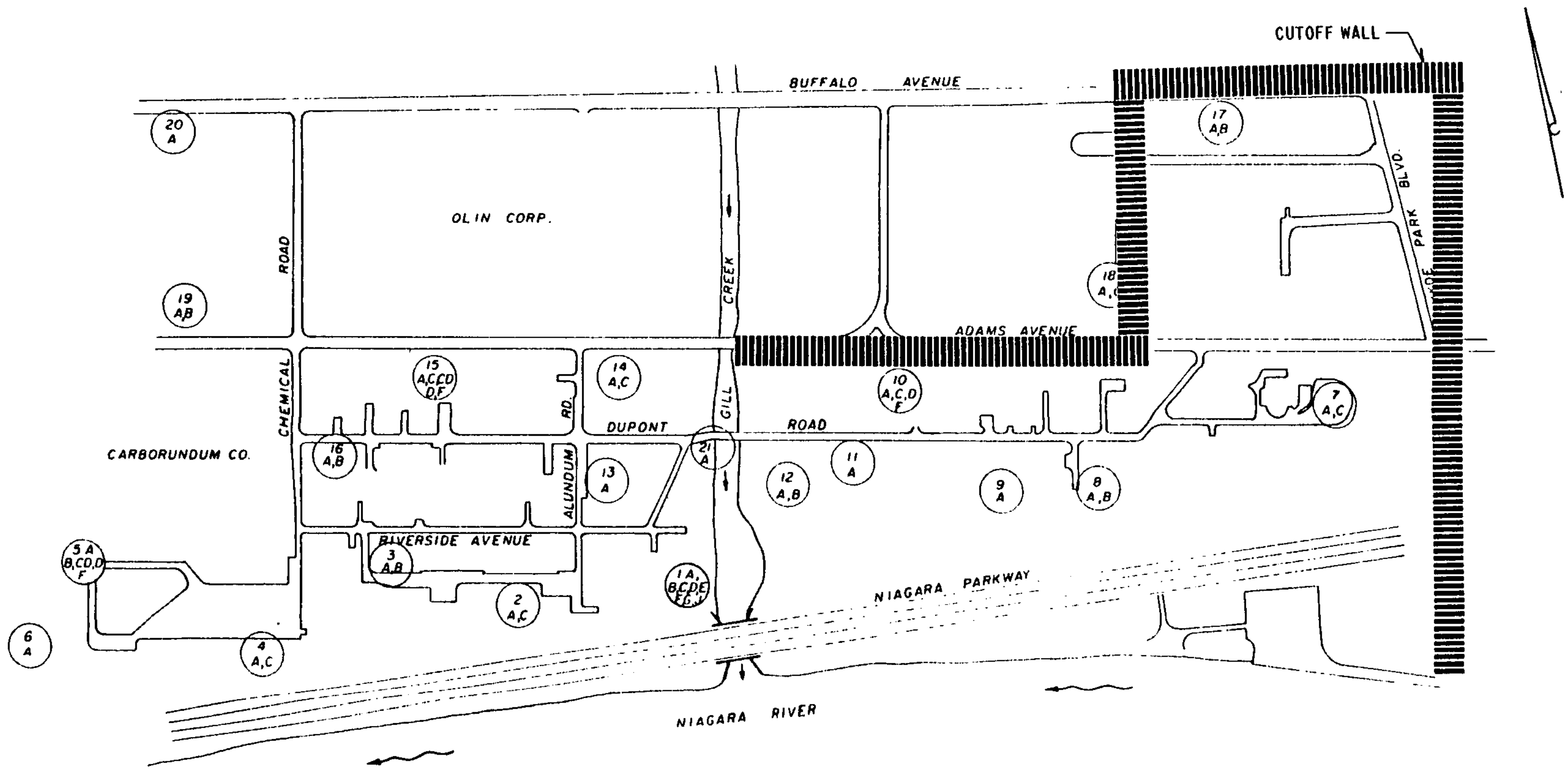
NOTE: ILLUSTRATIVE REPRESENTATION

CONCEPTUAL CUTOFF WALL - DOWNGRADIENT
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: D.W.B.	SCALE in FEET 0 — 300	DATE: 6/18/84	
CHECKED: C.R.C.		JOB: 83C2236-8	

PLATE 8



LEGEND:

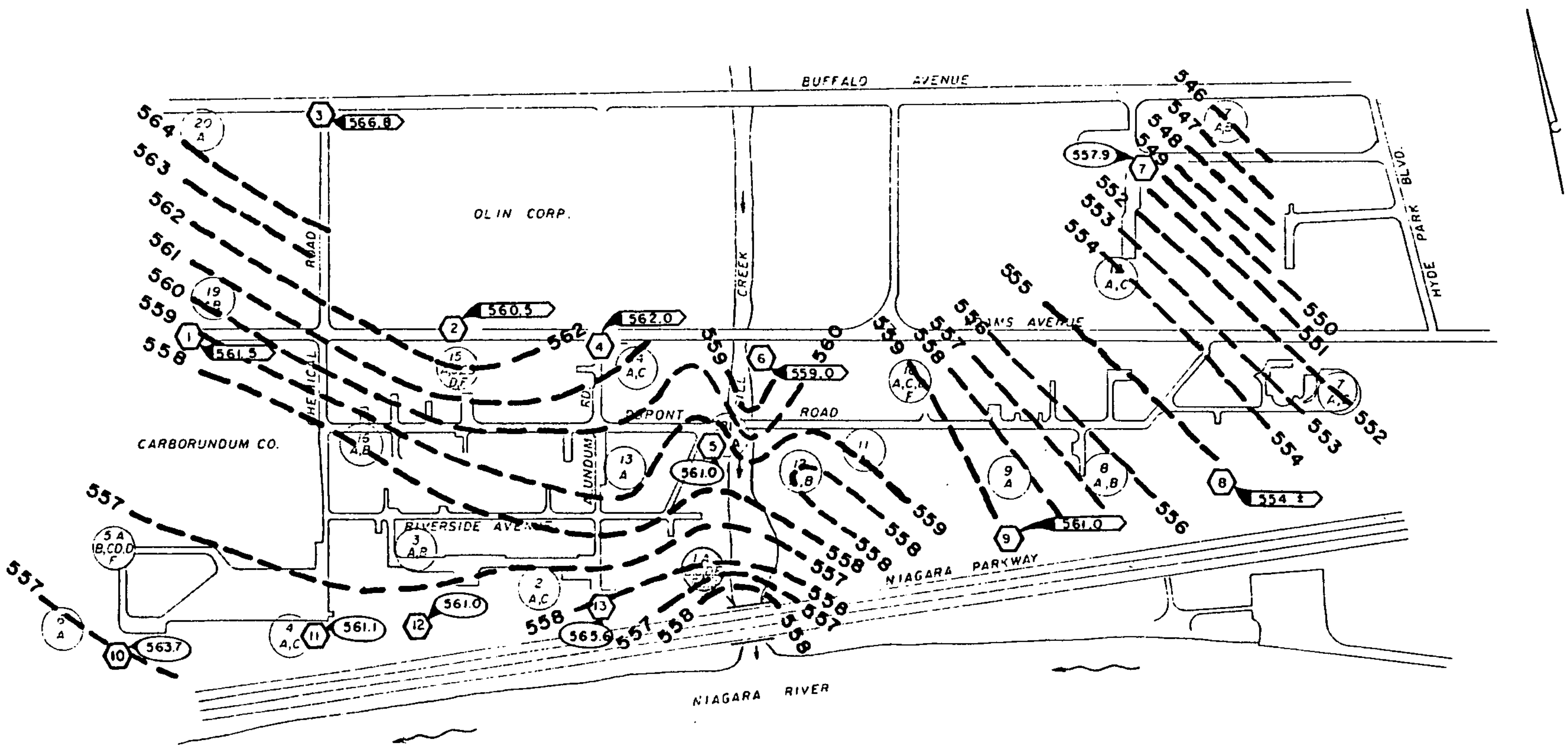
17 A,B — WELL CLUSTER NUMBER (NO.) — WELL TYPE (LETTER)

CUTOFF WALL - APPROXIMATE PERMEABILITY 10^{-6} cm/sec

NOTE: ILLUSTRATIVE REPRESENTATION

CONCEPTUAL CUTOFF WALL - ALTERNATE DOWNGRADIENT NIAGARA PLANT E. I. DUPONT DE NEMOURS & CO.			
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS			
DRAWN BY: D.W.B.	SCALE in FEET	DATE: 6/18/84	
CHECKED: C.R.C.	0 300	JOB: 83C2236-8	

PLATE 9



LEGEND:

(17 A,B) — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)

(X) — UTILITY WELL NUMBER

XXX.X — SPOT ELEVATION OF BEDROCK AT TEST PIT

(XXX.X) — ELEVATION OF BOTTOM OF TEST PIT - NO ROCK ENCOUNTERED

— — 557 ELEVATION OF TOP OF BEDROCK

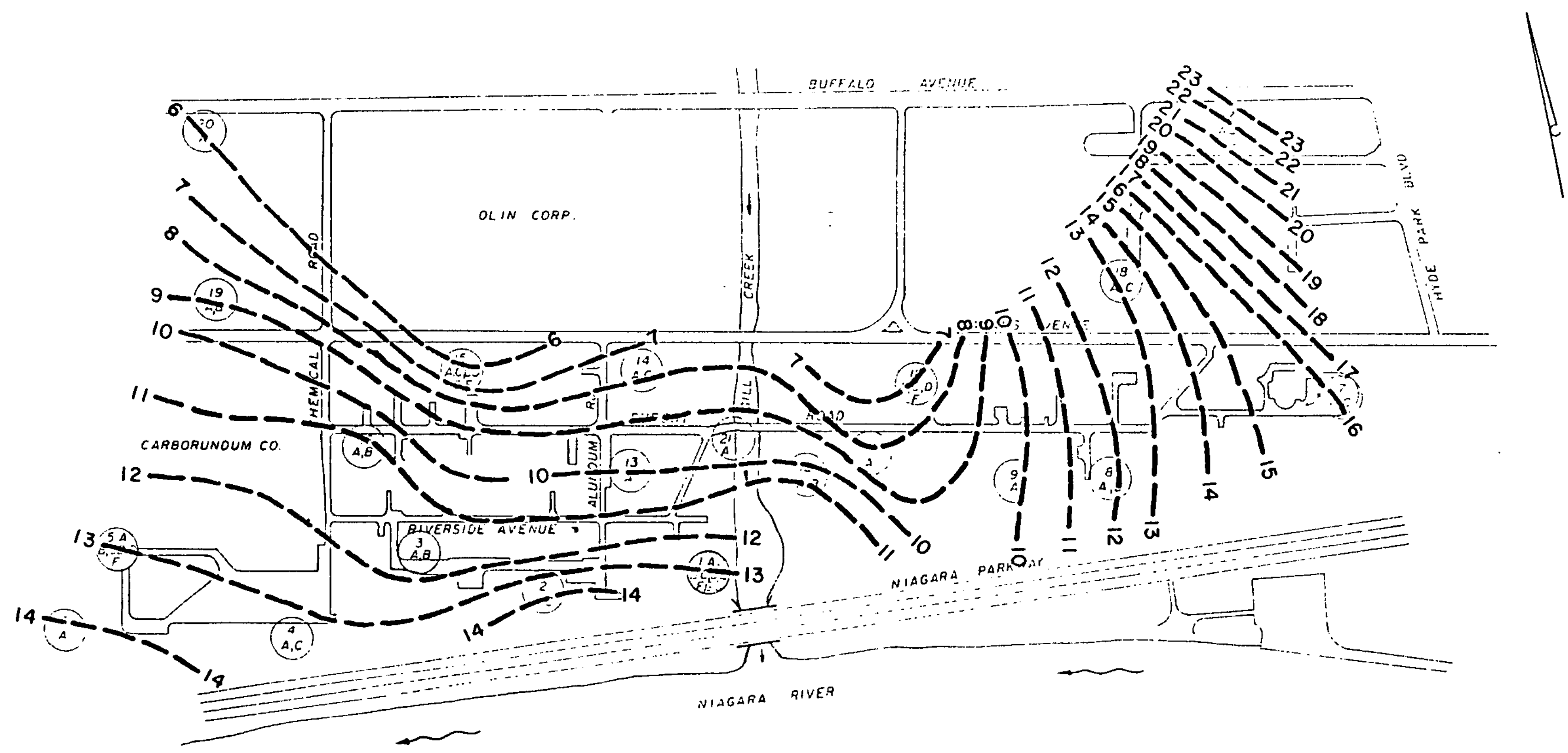
CONTOUR INTERVAL = 1 FOOT

INFERRED TOP OF BEDROCK STRUCTURE CONTOUR MAP
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: D.W.B.	SCALE in FEET 0 — 300	DATE: 6/18/84
CHECKED: C.R.C.		JOB: 83C2236-8

PLATE 11



LEGEND:

WELL CLUSTER NUMBER (NO.)

WELL TYPE (LETTER)

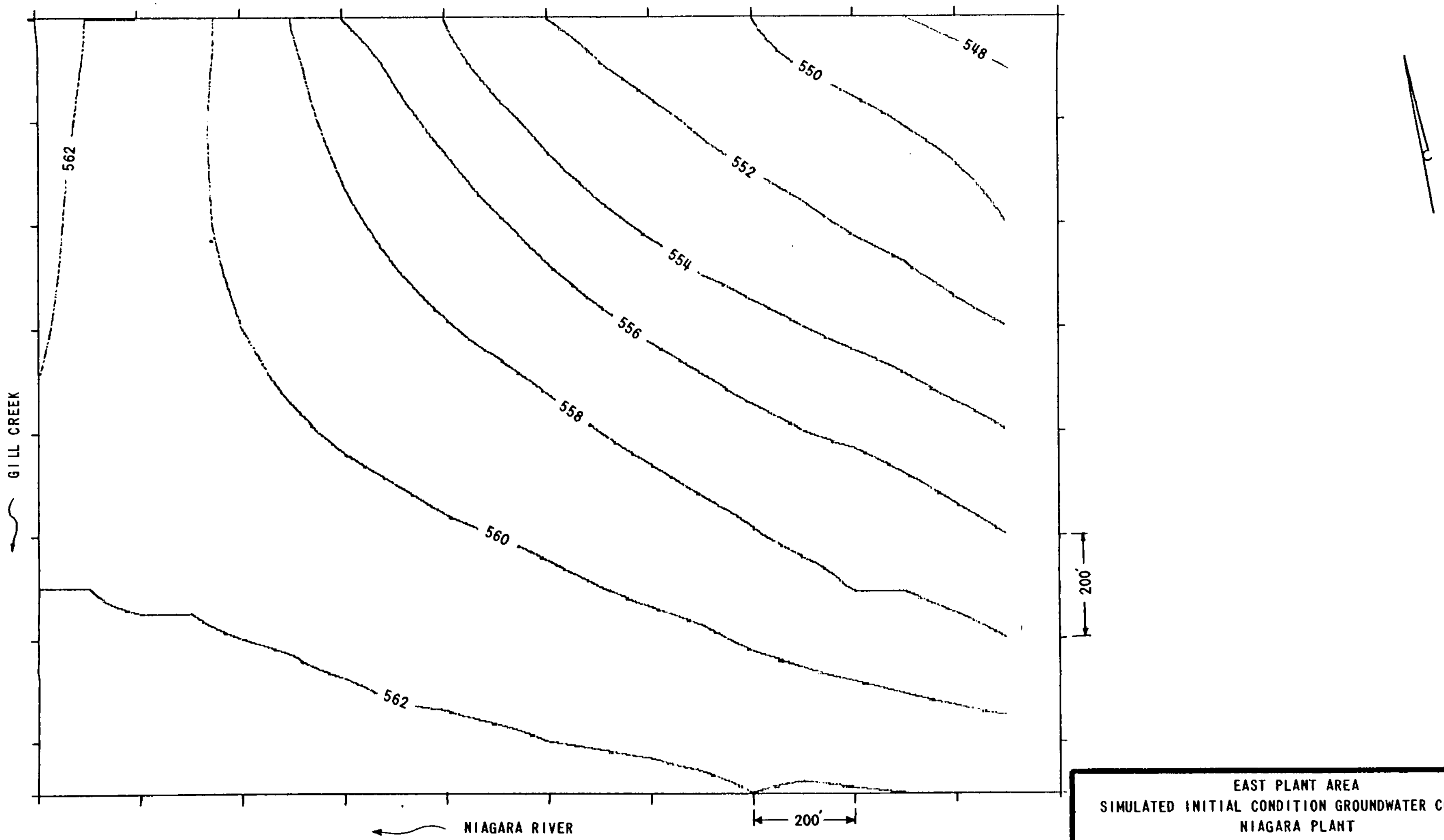
CONTOUR INTERVAL = 1 FOOT

ISOPACH MAP OF FILL/OVERBURDEN
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

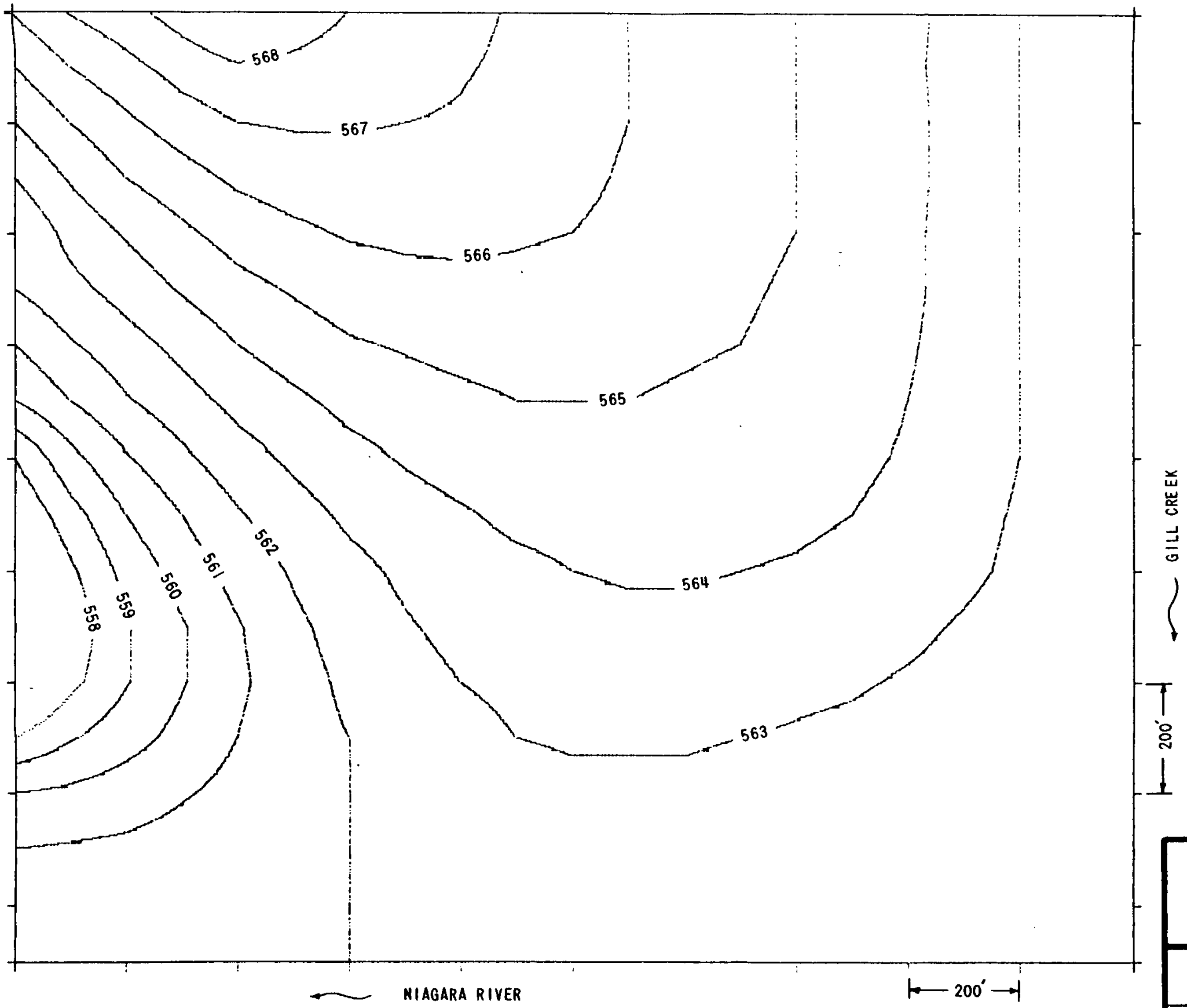
DRAWN BY: D.W.B.	SCALE in FEET	DATE: 6/18/84	
CHECKED : C.R.C.	0 300	JOB : 83C2236-8	

PLATE 12



EAST PLANT AREA SIMULATED INITIAL CONDITION GROUNDWATER CONTOURS NIAGARA PLANT E. I. DUPONT DE NEMOURS & CO.		
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS, GEOLOGISTS AND ENVIROMENTAL SCIENTISTS		
Drawn By D.W.B.	SCALE IN FEET	Date. 6/18/84
Checked: C.R.C.	AS NOTED	Job. 83C2236-8

PLATE 13

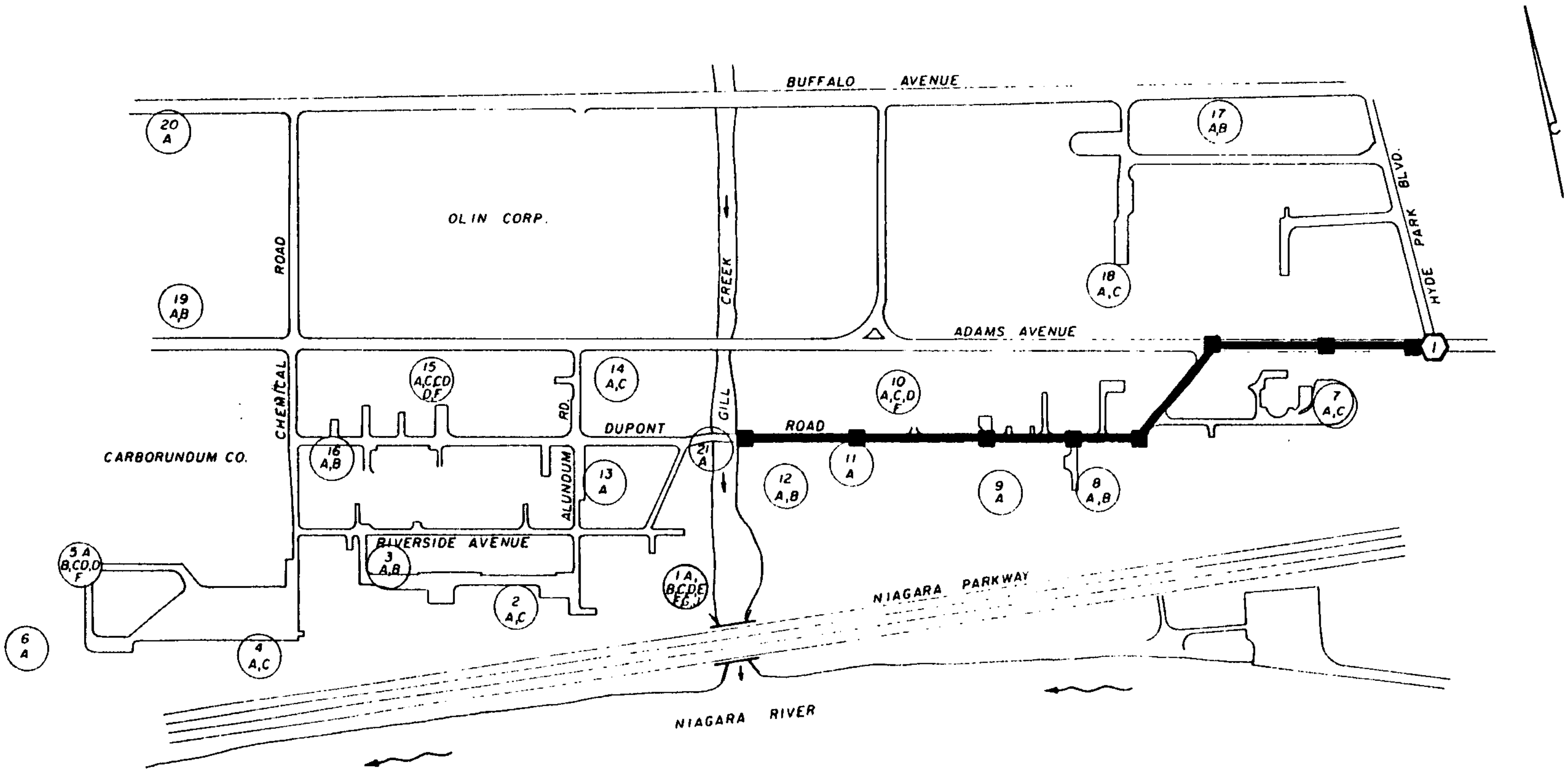


WEST PLANT AREA
SIMULATED INITIAL CONDITION GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIROMENTAL SCIENTISTS

Drawn By D.W.B.	SCALE IN FEET	Date 6/18/84
Checked C.R.C.	AS NOTED	Job 83C2236-8

PLATE 14



LEGEND:

(17 A,B) — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)

(1) PUMP

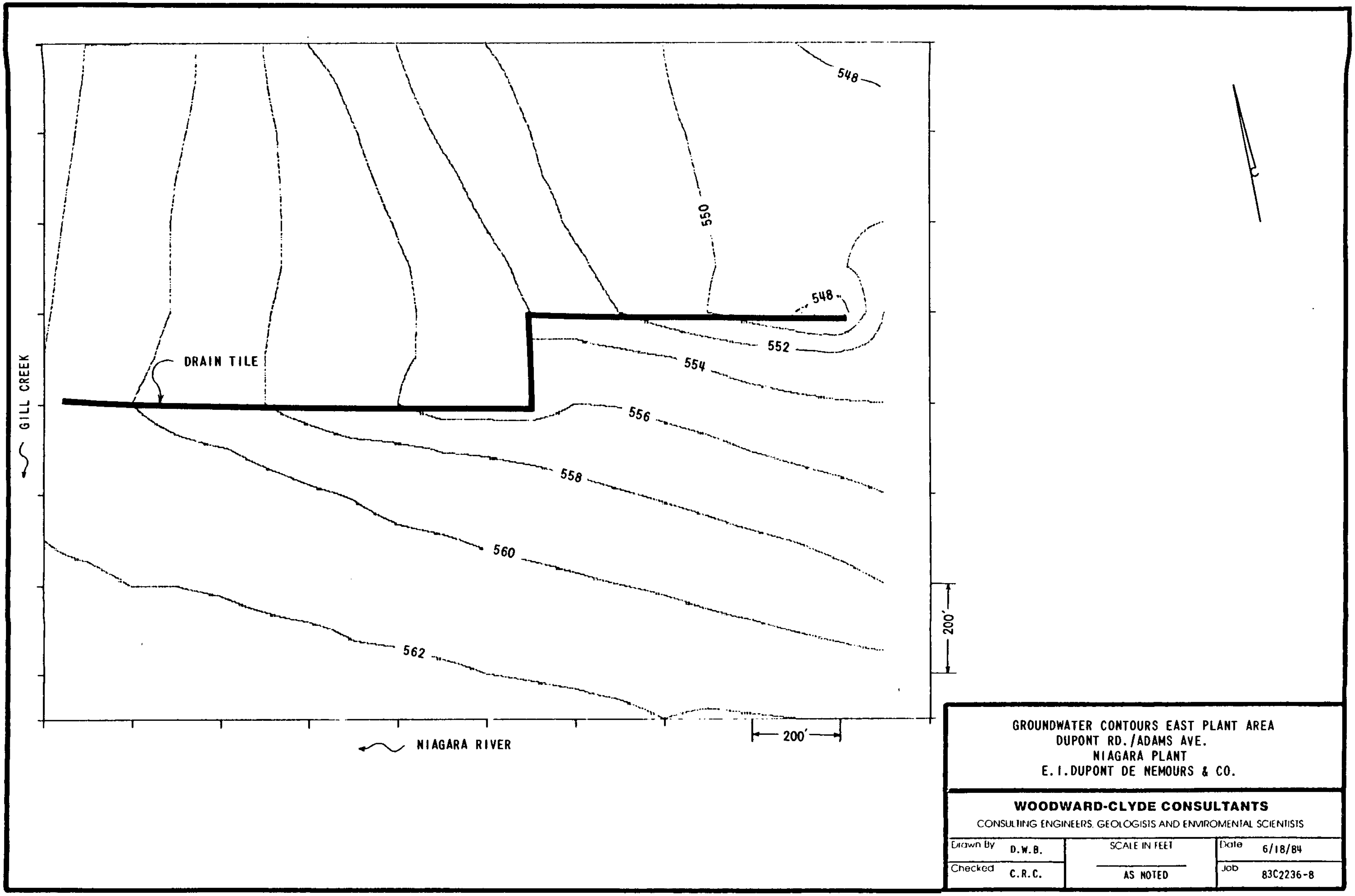
■ MANHOLE

DRAIN TILE COLLECTION SYSTEM
EAST PLANT AREA
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

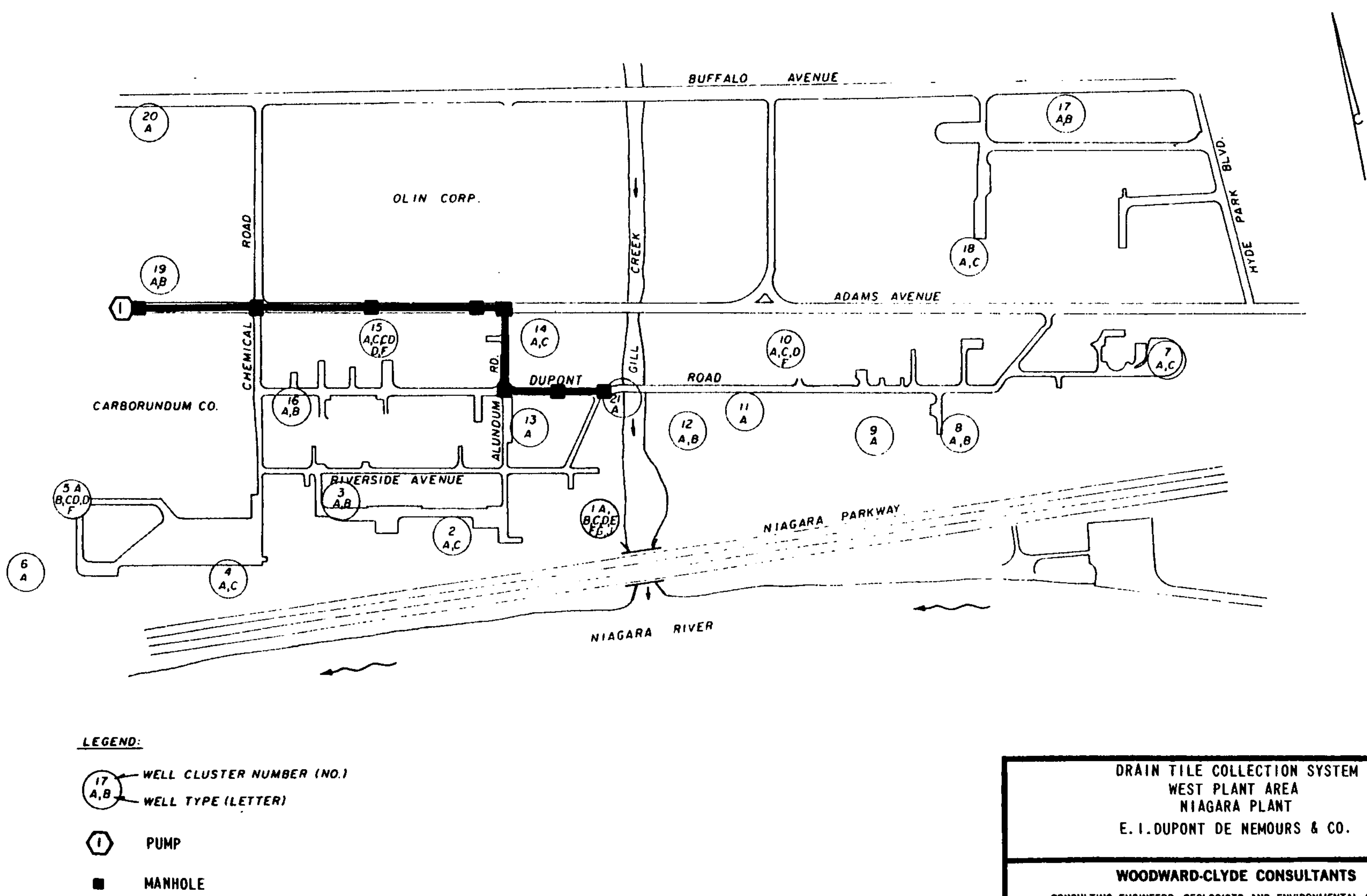
DRAWN BY: D.W.B.	SCALE in FEET	DATE: 6/18/84
CHECKED: C.R.C.	0 — 300	JOB: 83C2236-8

PLATE 15



GROUNDWATER CONTOURS EAST PLANT AREA DUPONT RD./ADAMS AVE. NIAGARA PLANT E.I.DUPONT DE NEMOURS & CO.			
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS, GEOLOGISTS AND ENVIROMENTAL SCIENTISTS			
Drawn By D.W.B.	SCALE IN FEET	Date 6/18/84	
Checked C.R.C.	AS NOTED	Job 83C2236-8	

PLATE 16

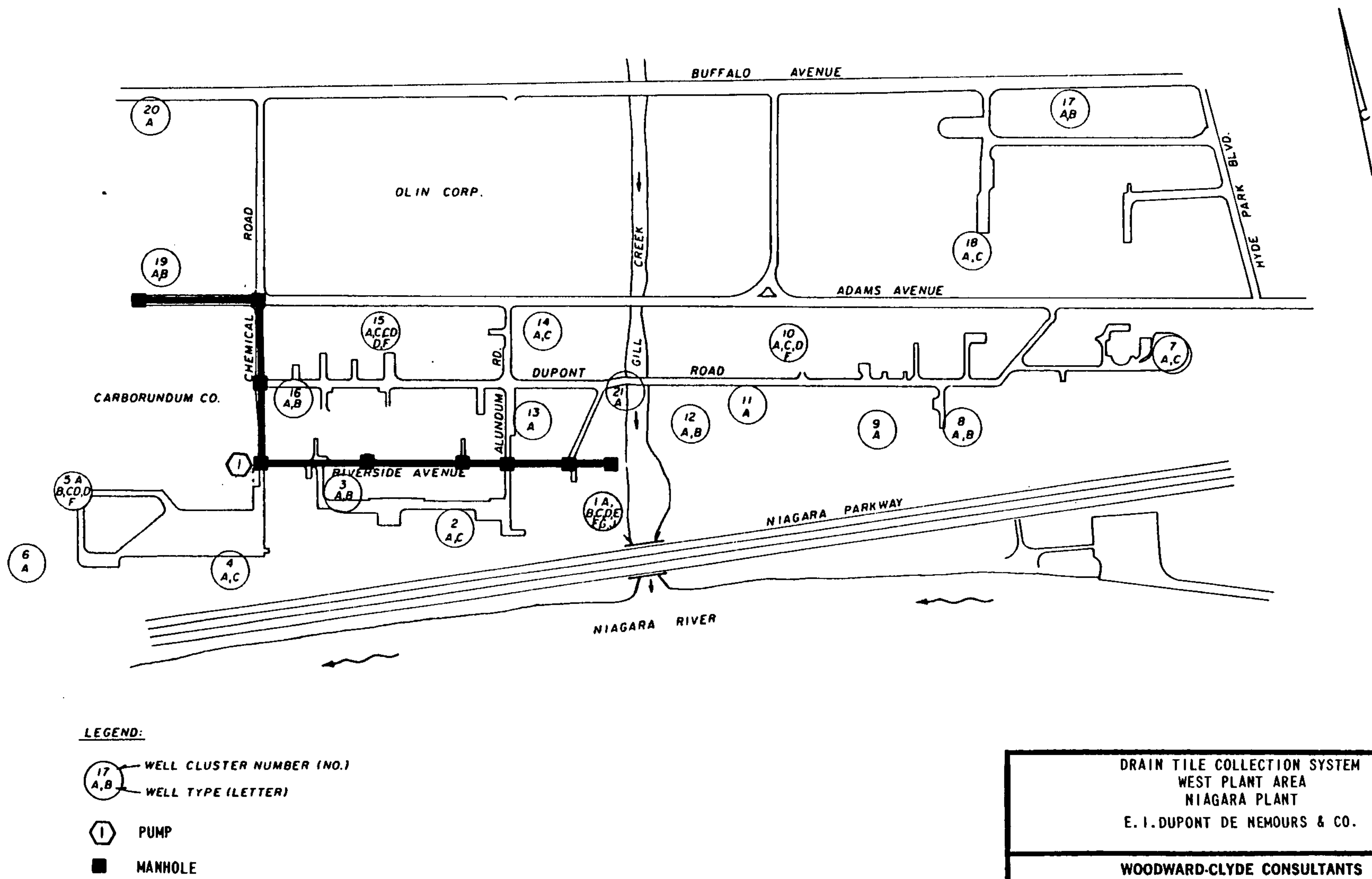


DRAIN TILE COLLECTION SYSTEM
WEST PLANT AREA
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: D.W.B.	SCALE in FEET	DATE: 6/18/84	
CHECKED: C.R.C.	0 — 300	JOB: 83C2236-8	

PLATE 17

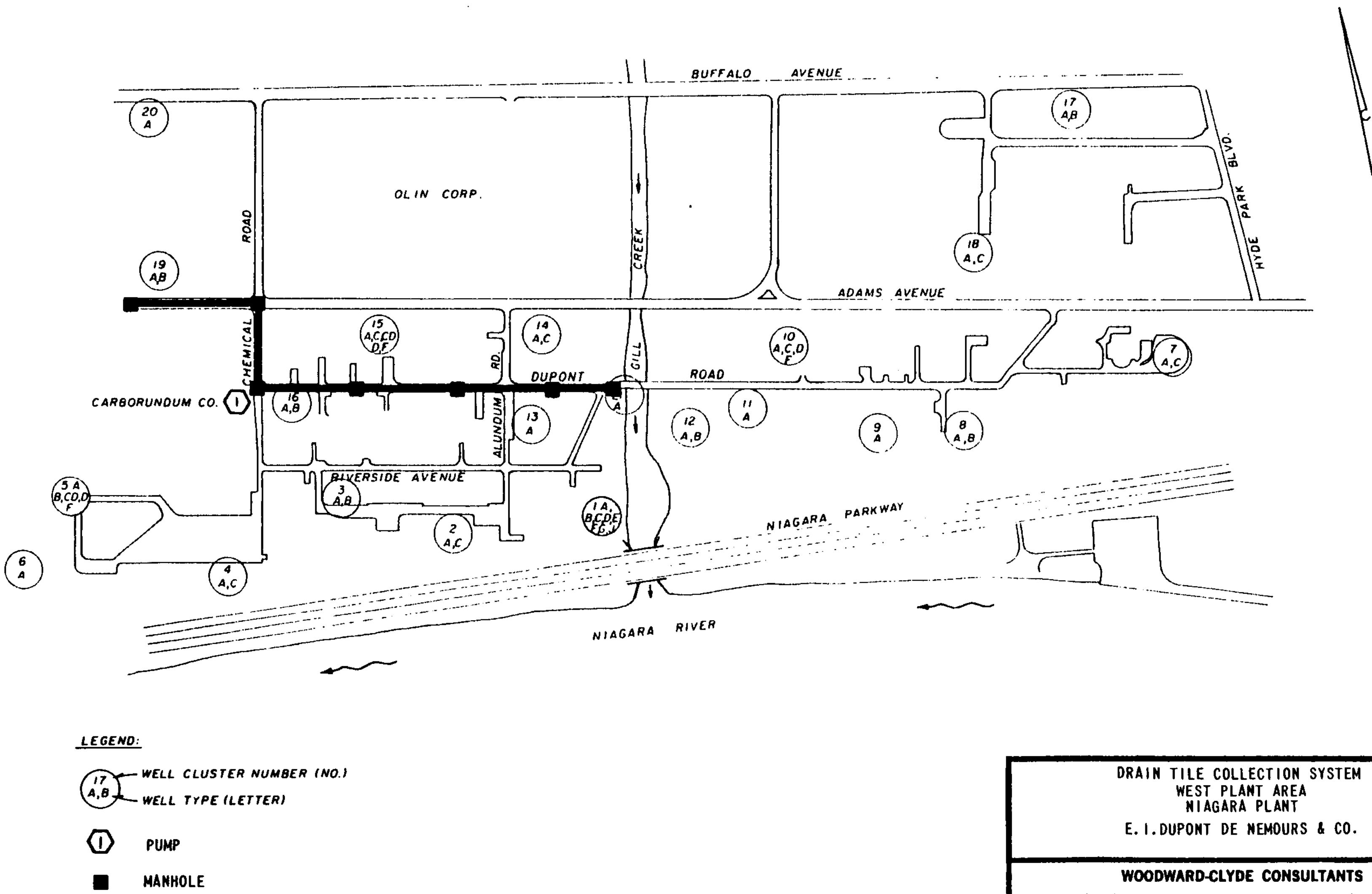


DRAIN TILE COLLECTION SYSTEM
WEST PLANT AREA
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: D.W.B.	SCALE IN FEET 0 — 300	DATE: 6/18/84
CHECKED: C.R.C.		JOB: 83C2236-8

PLATE 18



DRAIN TILE COLLECTION SYSTEM
WEST PLANT AREA
NIAGARA PLANT

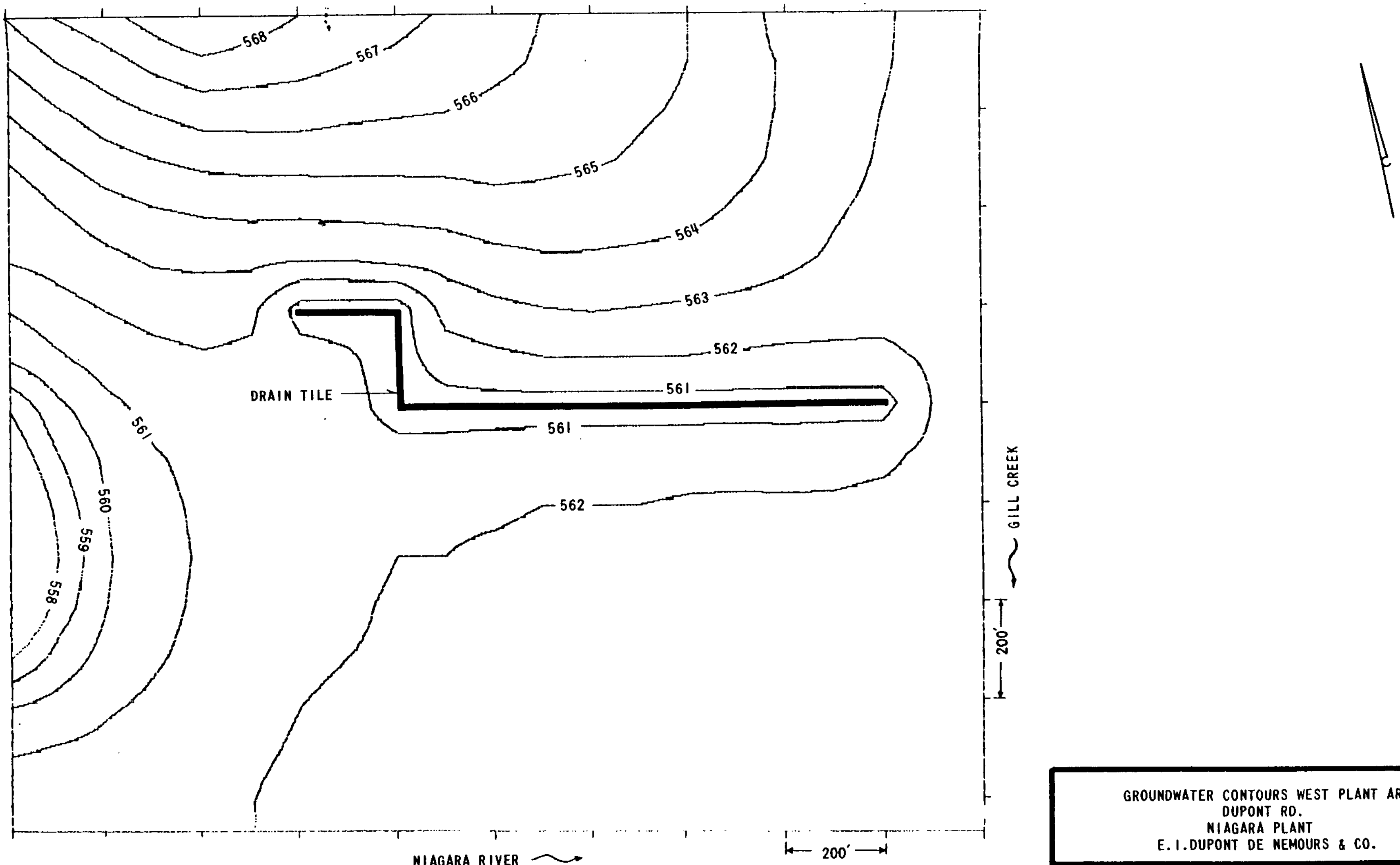
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: D.W.B.	SCALE in FEET 0 300	DATE: 6/18/84
CHECKED: C.R.C.		JOB: 83C2236-8

PLATE 19

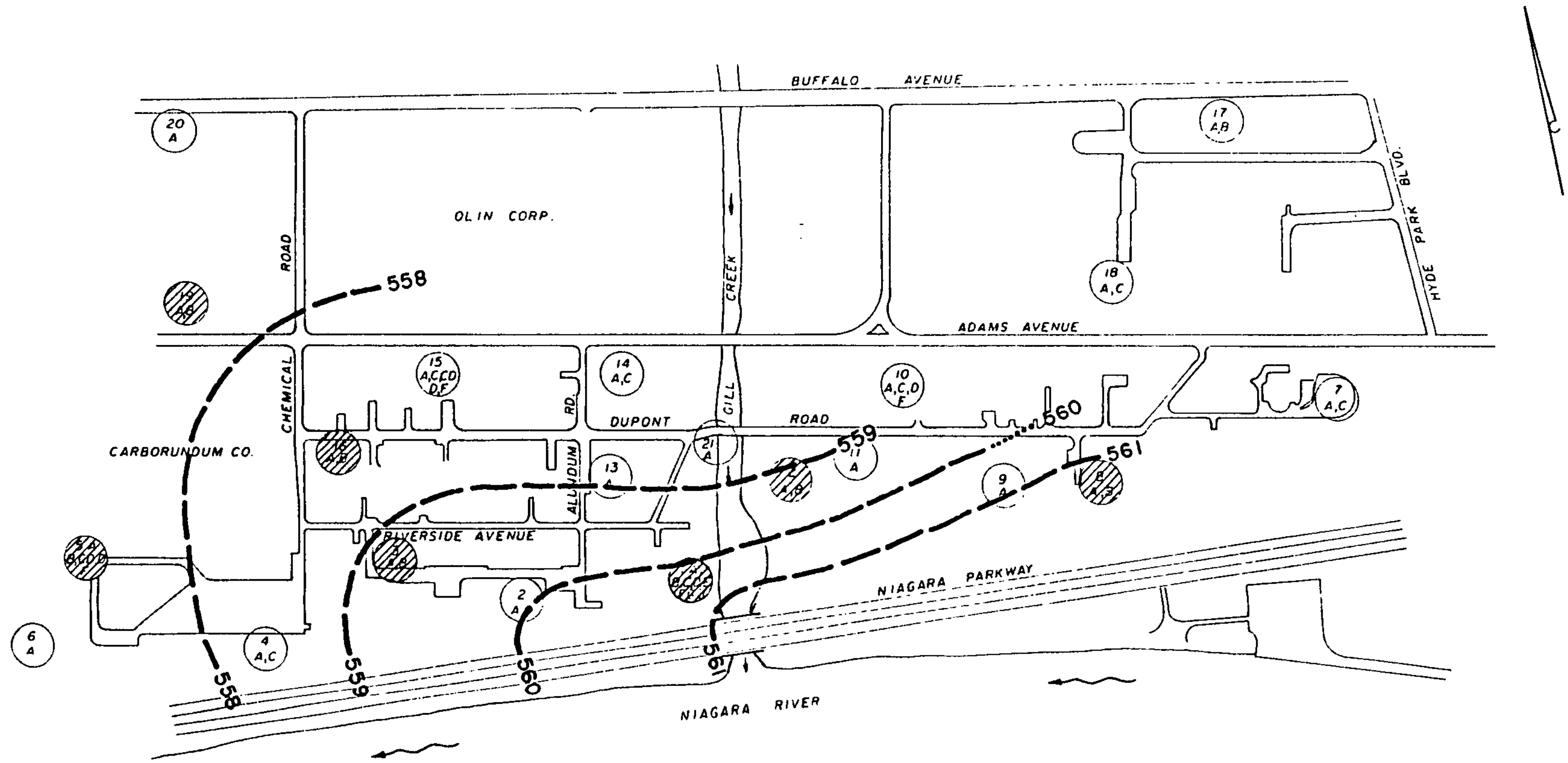


GROUNDWATER CONTOURS WEST PLANT AREA
DUPONT RD.
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIROMENTAL SCIENTISTS

Drawn By D.W.B.	SCALE IN FEET	Date	6/18/84
Checked C.R.C.	AS NOTED	Job	83C2236-7

PLATE 20



DURING RECOVERY TEST

OCTOBER 17, 1983, TIME ~ 1200

LEGEND:

17 A,B — WELL CLUSTER NUMBER (NO.) — WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

561 GROUNDWATER ELEVATION

NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM THAT SHOWN.

INFERRED B-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

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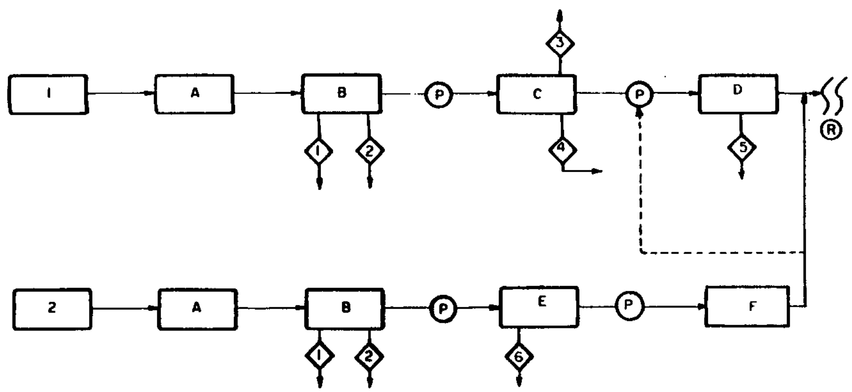
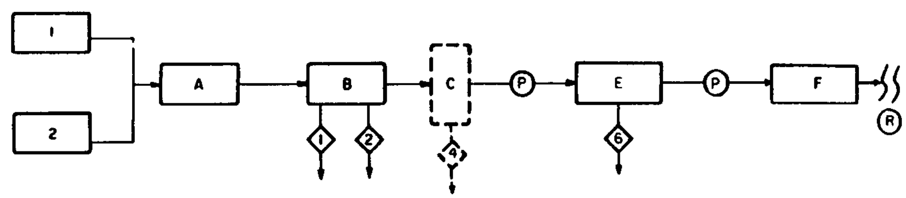
CHECKED: C.R.C.		JOB: 83C2236-8

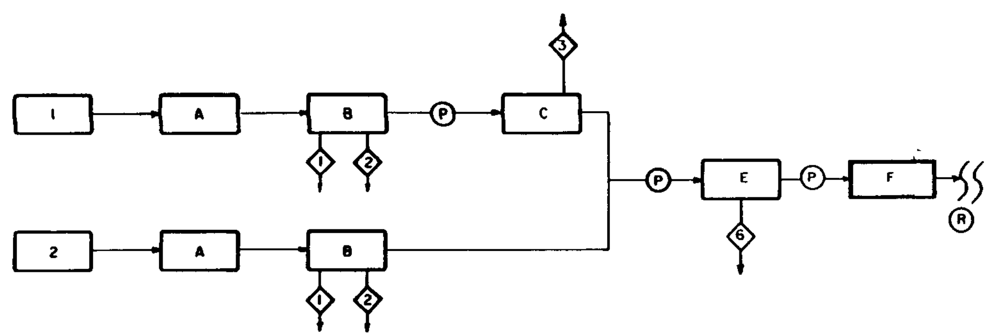
PLATE 21



ALTERNATE 1



ALTERNATE 2



ALTERNATE 3

LEGEND

SOURCES

1 = Remediation West Plant Area

2 = Remediation East Plant Area

TREATMENT UNITS

A = Receiving/Blending/Storing

B = Phase Separation (Floatable/Settleable non-aqueous)

C = Air Stripping (Includes vapor-phase activated carbon for off-gas, VPAC regeneration w/steam, regenerant separation)

D = Granular activated Carbon Adsorption

E = Bioreclamation (PACT Process)

F = Polishing Filter

P = Pumping Stage

R = Stream Discharge

STREAMS

1 Settled solids/liquids } off-site disposal

2 Floated liquids/solids } off-site disposal

3 Off-gas (air)

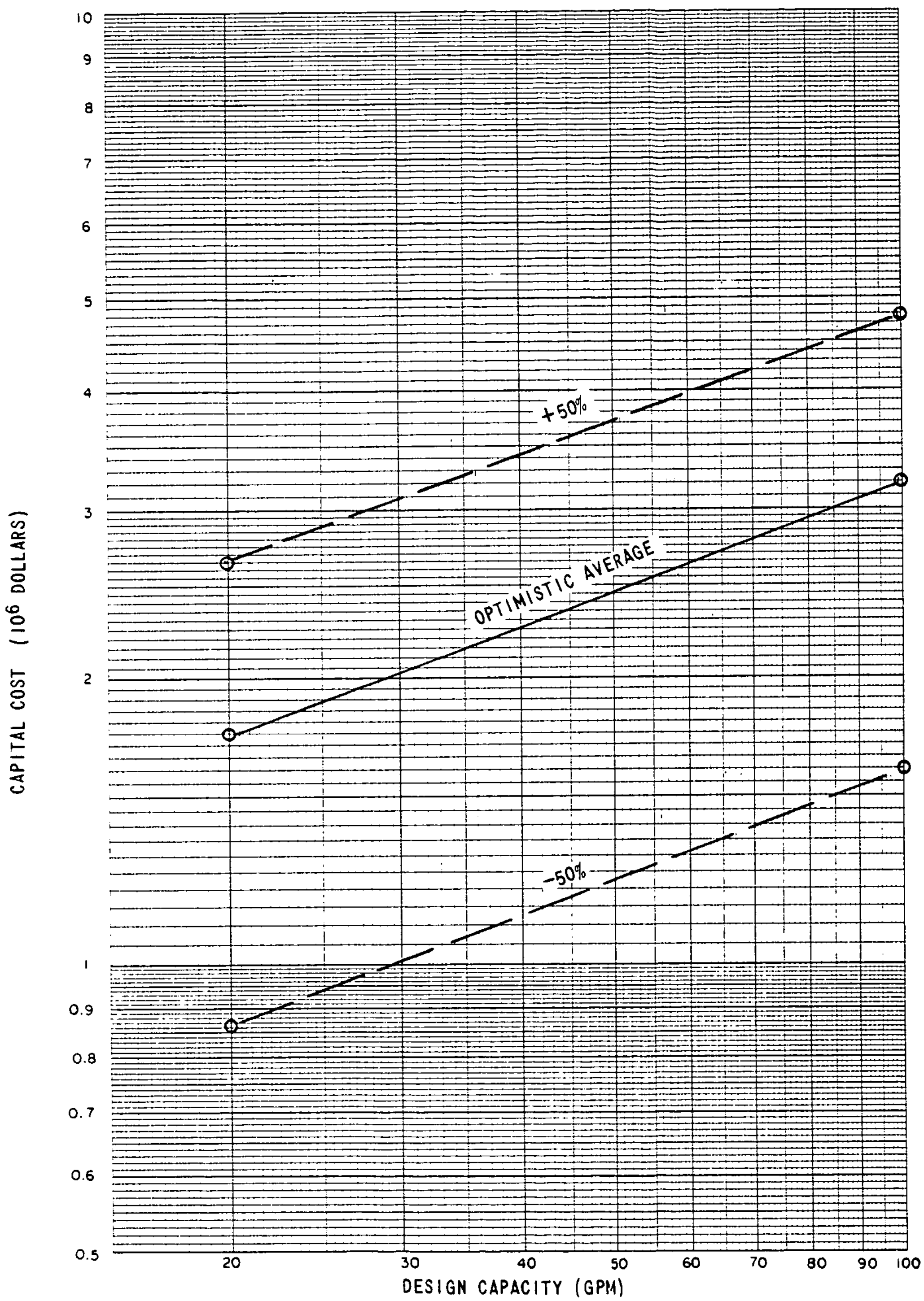
4 Recovered organics

5 Spent Carbon (off-site regeneration/disposal)

6 Excess Bio sludge and Carbon

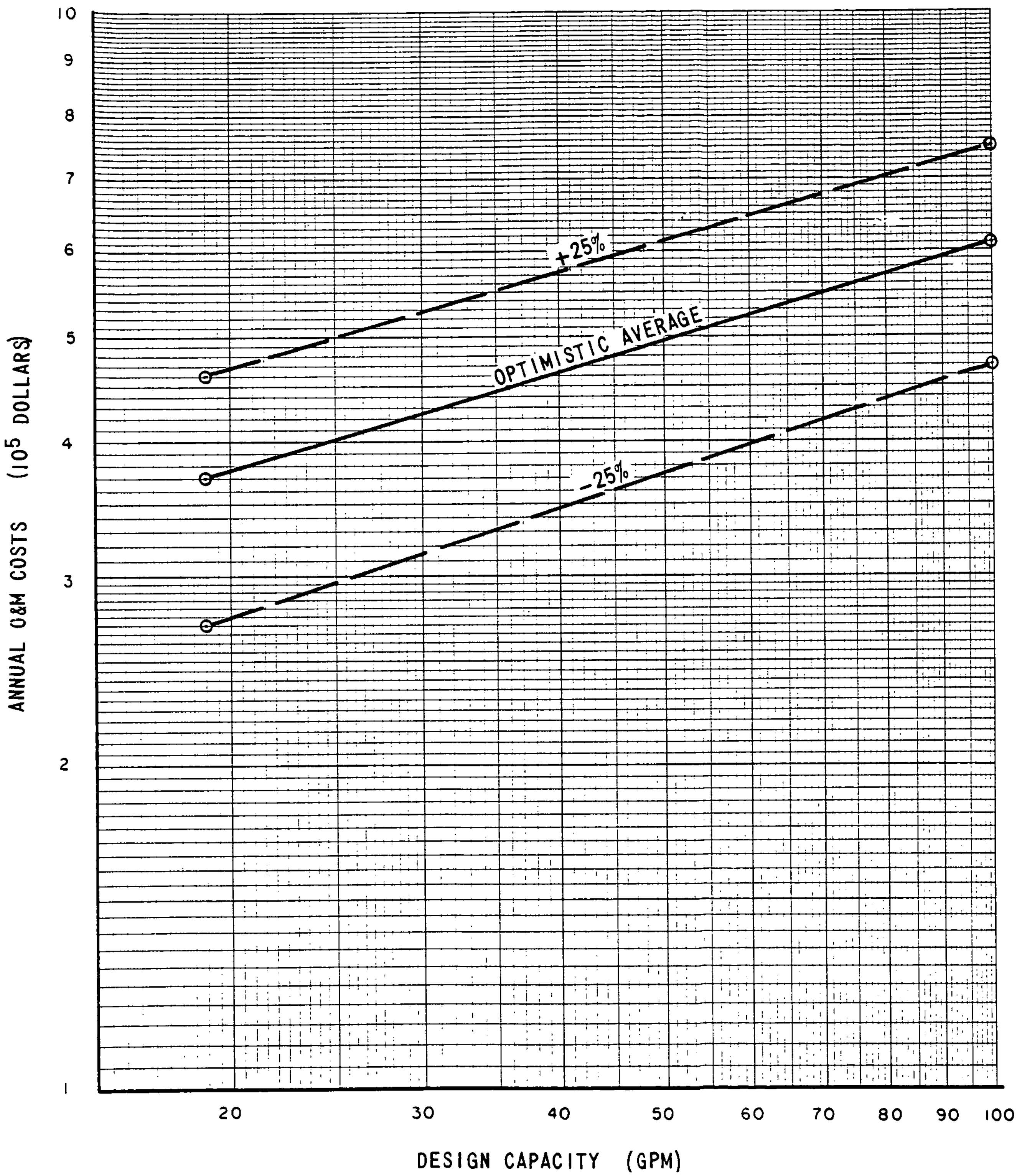
SIMPLIFIED SCHEMATIC REPRESENTATION OF POTENTIAL APPLICABLE REMEDIATION TRAINS
NIAGARA PLANT SITE
E.I. DUPONT DE NEMOURS & CO.
83C2236-8

PLATE 22



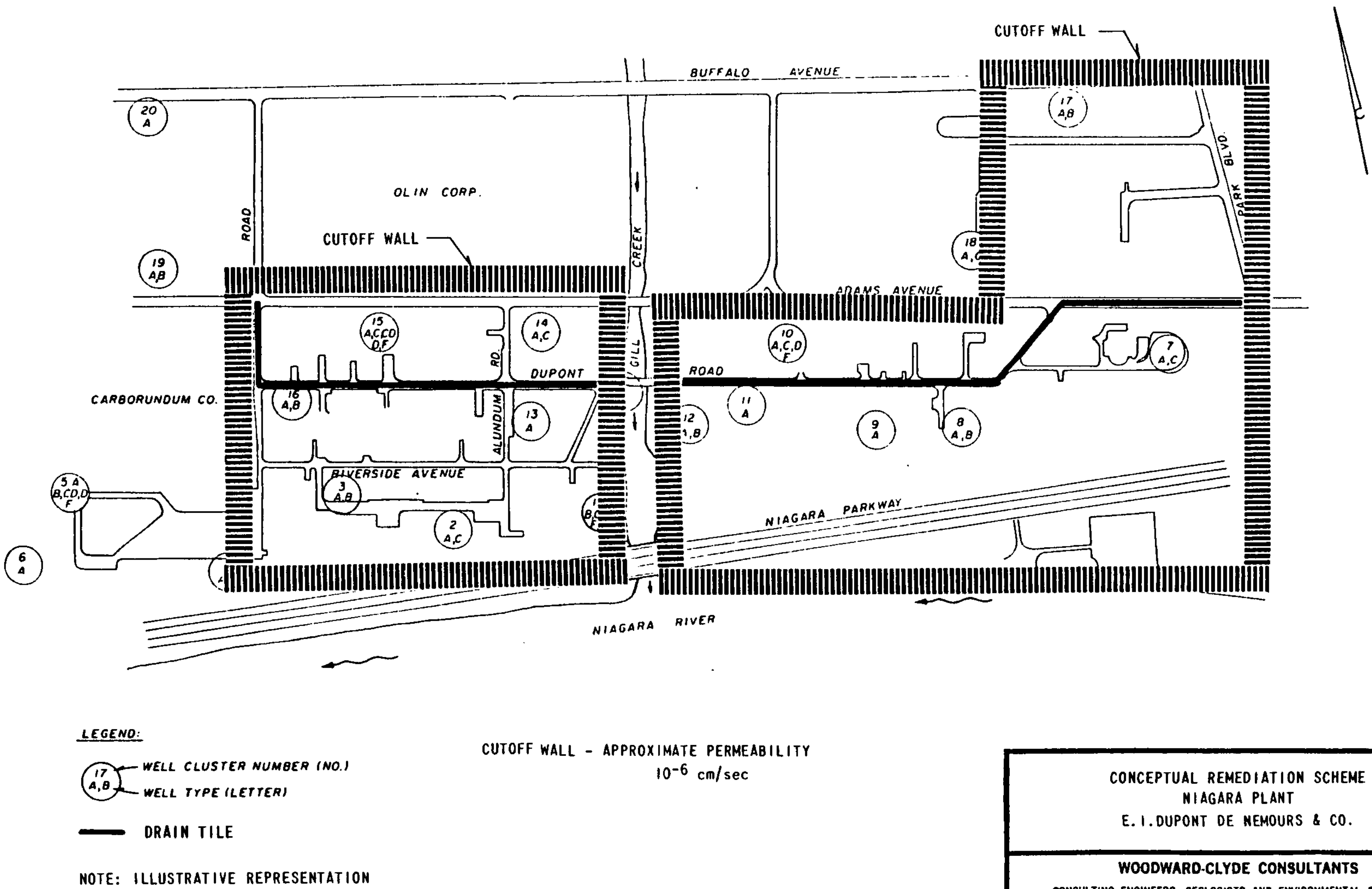
CAPITAL COST VS. CAPACITY
NIAGARA PLANT SITE
E.I. DUPONT DE NEMOURS & CO.
83C2236-8

PLATE 23



O&M COST VS. CAPACITY
NIAGARA PLANT SITE
E. I. DUPONT DE NEMOURS & CO.

PLATE 24



CONCEPTUAL REMEDIATION SCHEME
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
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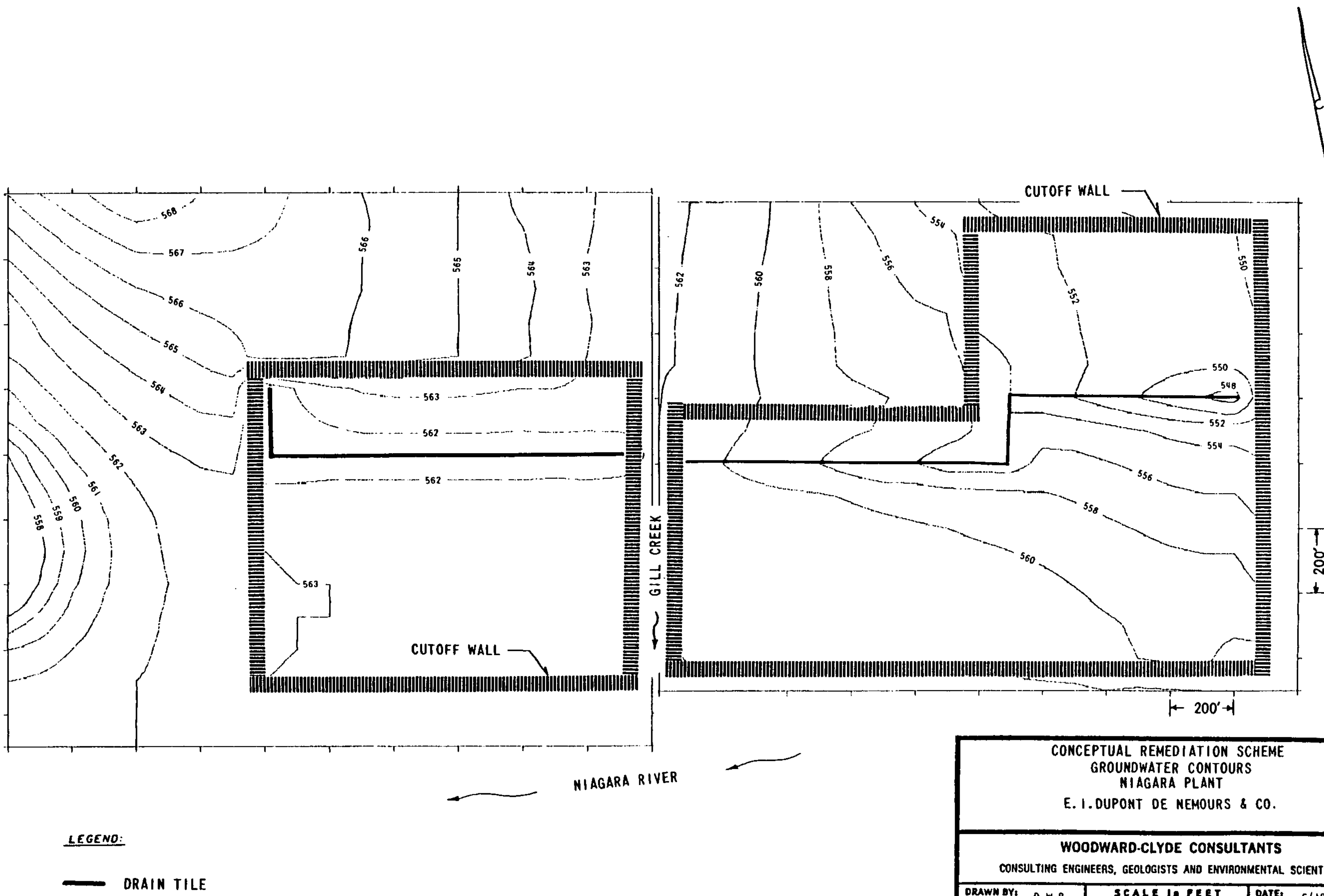
PLATE 25



CONCEPTUAL REMEDIATION SCHEME
GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

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PLATE 26

Appendix A

APPENDIX A
GROUNDWATER MODEL

The Prickett-Lonnquist computer model was used as part of the Phase II Remediation Studies. This is a widely used and well-documented two-dimensional finite difference numerical technique which models groundwater flow. The model solves a form of the transient flow equation which allows for the inclusion of heterogeneity and anisotrophy and can be used for both the confined and unconfined aquifer cases and to solve for both the steady state and transient conditions.

FINITE DIFFERENCE METHOD

A mathematical model for steady-state and nonsteady-state (transient) groundwater conditions consists of a set of governing differential equations and boundary conditions which simulate the flow of groundwater in a domain. A closed form solution of the equations results in determining the value of hydraulic potential head at any and all points in the domain. For most cases, however, a closed form solution of the governing equations is not obtainable. In these cases, approximate methods employing numerical techniques are utilized to solve the mathematical model. The numerical technique used in the studies described in this report is the method of finite differences. This approximate method provides a rationale for operating on the differential equations defining the model and for transforming them into a set of algebraic equations. Numerical solutions yield values for only a finite number of predetermined points in the problem domain. By limiting the need to know the head at a reasonable number of points, the set of partial differential equations is converted into a set of algebraic equations involving the number of unknown potentials. In using the finite difference method, a regularly or variably spaced grid is established in the flow domain. The intersection of grid lines are called nodes. The closer the node spacing selected, the closer the approximate solution approaches the "exact" analytical solution. Derivatives in the governing partial differential equations are replaced by differences taken between nodes. If the area defined by the grid spacing is small compared to the total area considered, then the discrete model is a reasonable representation of the continuous system.

MODEL CALIBRATION AND INPUT PARAMETERS

In order to investigate the effectiveness of the alternatives considered, it is first necessary to "calibrate" the model. This requires the input of historic hydrologic data followed by the varying of selected parameters such as groundwater head, hydraulic conductivity, and/or boundary conditions to arrive at an equilibrium condition which simulates the historic event conditions. The input data necessary to solve the Prickett-Lonnquist model consist of the following information:

1. Basic coefficients and variable values for the governing differential equations at each node:

- location in Cartesian coordinates
- column and row indices in the finite difference grid
- the directional hydraulic conductivity
- the storage coefficient
- net volumetric discharge

2. definition of boundary conditions

3. initial estimate of head for the historic event simulated

4. the time step and the allowable error of convergence.

Appendix B

APPENDIX B
SUMMARY OF PRELIMINARY DESIGN BASIS AND MAJOR UNIT SIZING FOR RECOMMENDED ALTERNATIVE 9

Design Flow Rate

West Area	7 gpm x 1.5 (design factor) ≃	10 gpm
East Area	13 gpm x 1.5 (design factor) ≃	20 gpm
		30 gpm

Wastewater Characteristics - Refer to Table 7 of this Report

Location and Arrangement - Refer to Plates C-1 and C-2

1. **Receiving/Blending/Storage Unit for West Area**

Function Receive, combine and provide surge capacity for collection system pump discharges from West Area

Number of Units One

Type Vertical, cylindrical covered steel tank, epoxy or equal coating

Capacity 24-hour storage (15,000 gallons)

Auxiliaries Slow-speed mechanical mixer (approximately 1 HP), vent control, level recorder/alarm, emergency overflow.

Function	Receive, combine and provide surge capacity for collection system pump discharges from East Area
Number of Units	One
Type	Vertical, cylindrical covered steel tank, epoxy or equal coating
Capacity	24-hours storage (30,000 gallons)
Auxiliaries	Slow-speed mechanical mixer (approximately 1 HP), vent control, level recorder/alarm, emergency overflow

3. **Phase Separation for West Area**

Function	Separate and remove settling and floatable solids and non-aqueous phase liquids from contaminated groundwater
Number of Units	Two (includes spare)
Type	Rectangular oil/sludge separator, steel construction with epoxy or equal coating
Size, Each	Approximately 3'x7'x4' SWD (or equivalent "package" oil separator)
Auxiliaries	Sludge hoppers, manual sludge drawoff control and surface skimmer, scum/sludge decanter sumps (40 cubic feet each), pumps for transfer to tankwagon for off-site disposal

4. Phase Separator for East Area

Function	Separate and remove settling and floating solids and non-aqueous phase liquids from contaminated groundwater
Number of Units	Two (includes spare)
Type	Rectangular oil/sludge separator, steel construction with epoxy or equal coating
Size, Each	Approximately 4.5'x9'x5' SWD (or equivalent "package" oil separator)
Auxiliaries	Sludge hoppers, manual sludge drawoff control and surface skimmer, scum/sludge decanter sumps (40 cubic feet each), pumps for transfer to tankwagon for off-site disposal

5. Air Strippers for West Area

Function	Reduce individual VOC concentrations to 50-75 mg/L
Number of Units	Two
Type	Counter-current packed tower, forced draft
Size, Each	2' diameter x 18' high (height of packing 15')
Packing Mat'l	2" plastic tellerettes
Air Flow	200 ACFM, each tower

Auxiliaries — Blowers (three, including one common spare). Feed pumps (three, including one common spare)

6. Vapor-Phase Activated Carbon Adsorbers for Stripper Off-Gas West Area

Function — Reduce stripper off-gas VOC content to meet NYDEC AAL limits

Number of Units — Two, one for each stripper

Type — Dual chamber, packed bed granular carbon adsorbers

Capacity — 600 CFM air flow; 600 lbs carbon each

Auxiliaries — Fan, air preheater (to adjust humidity to 50%), adsorption/desorption/purge/cooldown controller, condenser-separator and condensate storage

7. Powdered Carbon - Assisted Biotreatment (PACT) Unit for East Area

Function — Reduce TOC of contaminated groundwater so that combined treated discharge is 10 lbs/day or less

Number of Units — One, dual parallel train system

Components — Skid-mounted (licensed) system, including aeration tanks, clarifier sections, carbon and polymer feed, sludge recycle pumps and controls, aeration blowers and diffusers, sludge and spent carbon wasting controls

Design Basis — Reduce influent TOC of 40-50 lbs/day to less than 7 lbs/day in effluent

Auxiliaries	Spent carbon/excess biological sludge holding/aeration tank for 5-days production (1,500 gal.)

8. Polishing Filter for East Area Biotreated Effluent

Function	Reduce residual biological or carbon solids in clarifier effluent to 20 mg/L
Number of Units	One, dual parallel unit
Type	Dual-media, pressurized down-flow filter
Design Criteria	Hydraulic loading <3 gpm/ft^2; approximate surface area - 7 ft^2/unit; backwash rate - 15 gpm/ft^2; backwash disposal - recycle to PACT system influent
Auxiliaries	Cycle controller (time or ΔP), backwash pumps and sump, filtrate well

9. Liquid Phase Granular Activated Carbon Adsorption Unit for East Area (or Combined)

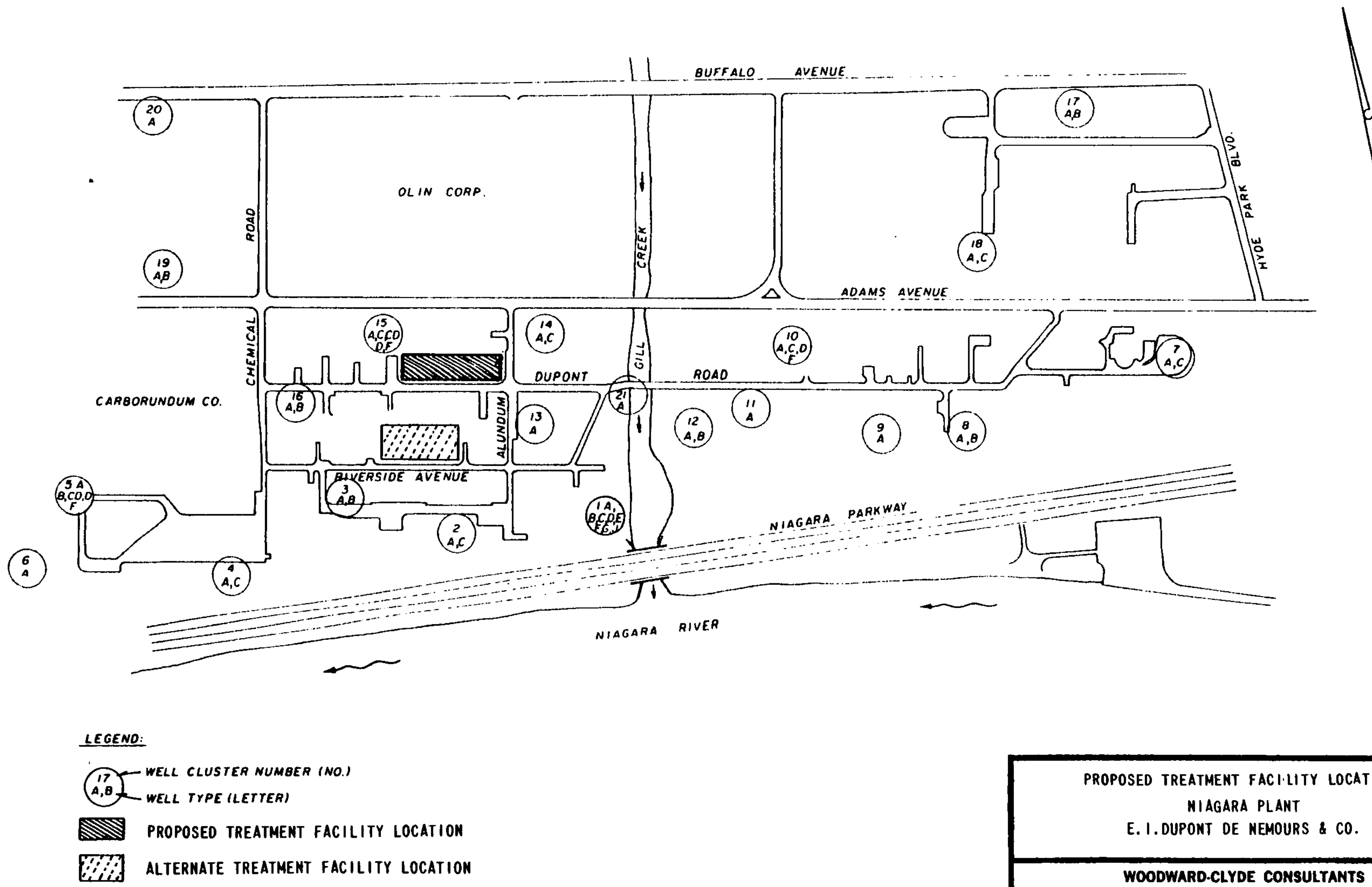
Function	Remove TOC from pre-stripped groundwater (and from biotreated effluent, if appropriate)
Number of Units	One, dual parallel unit
Type	Skid-mounted, pressurized down-flow backwashable packed bed (possibly modular unit as from Calgon - capable of flow rate equivalent to combined flow from East and West Areas)

<u>**Design Factors**</u>

Hydraulic loading - <2 gpm/ft^2; organic loading -0.116 TOC/lb C; empty bed displacement time - >30 minutes

<u>**Auxiliaries**</u>

Backwash sump and pumps. Spent carbon and virgin carbon storage tanks, carbon transfer pumps



PROPOSED TREATMENT FACILITY LOCATION NIAGARA PLANT E. I. DUPONT DE NEMOURS & CO.		
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS		
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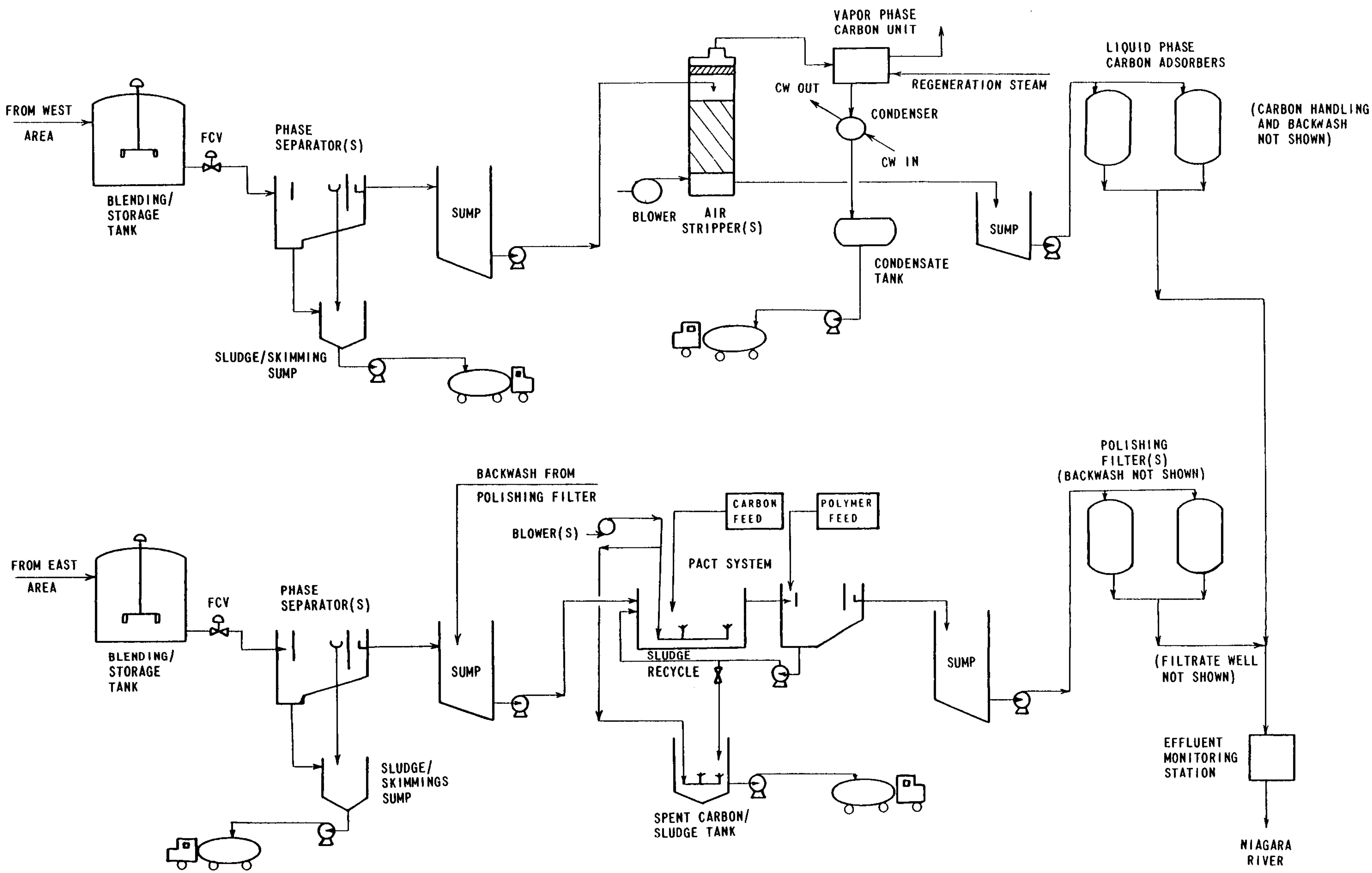
CHECKED: C.R.C.		JOB: 83C2236-8

PLATE B-1



SCHEMATIC FLOW DIAGRAM - TREATMENT ALTERNATIVE
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

PLATE B-2

Appendix C

APPENDIX C
CONCEPTUAL DESIGN
DRAIN TILE COLLECTION SYSTEM
AND SLURRY TRENCH CUTOFF WALL

DRAIN TILE COLLECTION SYSTEM

As discussed in the text, the location of the drain tile collection system for both the east and west plant areas is primarily along DuPont Road. The modeled location of these drain tile collection systems are schematically presented on Plate C-1. The following details are presented as conceptual design details. Some modification of these details would be expected final design studies. The main components of the drain tile collection system are as follows:

- 8-inch perforated clay drain tile, bell and spigot variety with slip joint, as shown on Plate B-2,
- access manholes, maximum 300-foot spacing and at the ends of each run (typical detail shown on Plate B-3),
- pump manholes for collection of the groundwater via drain tile collection system, and submersible pump (typical detail for the pump manhole shown on Plate B-4),
- stainless steel pump capable of pumping 50 to 100 gallons per minute at a 50-foot head loss, and
- 4-inch galvinized steel return line to the treatment facility.

In general, the construction procedure would be to excavate to top of rock with a penetration into the rock of approximately 8 to 10 inches. Shoring and groundwater control measures would probably be required for inspection and installation of the drain tile collection system. The bottom of the excavation should be examined for fractures in the bedrock. Upon completion of this examination, a grouting program or other type of rock surface liner to seal the potential crack zones may be required. After the sealing of the bedrock, a minimum of four inches of bedding (filter material) consisting of well-graded durable sand with the gradation such that D_{85} (85 percent fines) size should be no smaller than one-half the diameter of the perforation and no more than 10 percent of the filter material should pass the No. 60 sieve. The perforated clay tile drain should be laid on the bedding material with the perforations at the bottom. Backfill with the filter material should proceed to an elevation corresponding with the horizontal mid plane of the pipe and compacted. In general, installation of the perforated clay pipe should follow the procedures established in ASTM C12-82. Above the midplane elevation, backfill with the on-site materials and compaction of the placed material can proceed. At least one foot of material should be placed over the top of the pipe before any compactive effort is applied. It is noted that, for the leg of the tile drain system along Chemical Road and Adams Avenue, the existing sewer system is below the top of rock elevation. Therefore, it may be necessary to create a barrier at the elevation of the top of rock along the alignment of this sewer system to mitigate the migration of contaminants in the bedding materials along the existing sewer line. It is proposed that the installation of the new tile drain system be constructed in a plane parallel to the alignment of the existing sewer lines on the respective streets. In doing so, a minimum disturbance to the existing line serviceability and integrity can be affected. In addition, the lines can then be treated individually should excavation and repair of either system be required at a later date.

Manholes are to be constructed of precast concrete sections or brick and spaced a maximum distance of 300 feet apart along the collection line, at changes in direction of the drain tile line, or where significant changes in invert elevation occur in the drain tile line. The location of these manholes are tentatively located as shown on Plate B-1. The pumping manholes for the east and west plant areas would be located at the intersection of Adams Avenue and Hyde Park Boulevard, and of DuPont and Chemical Road, respectively. The construction of these manholes should be such that it can accommodate a slide rail for easy maintenance of the submersible pump. Again, the depth of this manhole would be somewhat deeper than the top of rock to facilitate the dual function as a siltation pit and a collection well for possible non-aqueous liquids.

In conjunction with manhole construction and the installation of the drain tile collection system, a four-inch galvinized steel pipe would be installed as a return line from the pumps to the treatment facility. The installation of the return line would be coordinated with the construction of the drain tile system and manholes and would be located at least four feet below the surrounding ground surface. After installation of the return line, backfilling should proceed to the design subgrade elevation. A standard detail for pavement would be used to complete the operation.

Although the construction of this drain tile collection system in the roadway considerably reduces the amount of interference which would have occurred had the system been located in the process area, proper care should be taken when laterals to the existing sewer system and other utility lines are encountered so as to limit service disruption. To reduce the potential to disrupt services, it is recommended that an in-depth review of the locations of various utilities and a physical survey be conducted prior to any construction. In addition, to confirm that the variations in the bedrock are not significantly different than those presented on the inferred top of bedrock plate, a test drilling program along the alignment of the proposed drain tile collection system should be conducted to better detail the top of rock profile and the condition of the rock at the rock overburden interface.

SLURRY TRENCH CUTOFF WALL CONSTRUCTION

It is proposed that a slurry trench cutoff wall be constructed around both the east and west plant areas. The slurry trench cutoff wall would be constructed by excavating a narrow vertical trench typically two to four feet in width. The trench would be excavated through the overburden materials and keyed into the relatively impermeable bedrock stratum below. It is anticipated that in the areas where shot rock is encountered standard excavation techniques will be adequate to accomplish the construction of the cutoff wall in these areas. If not, it may be necessary to excavate through the shot rock areas utilizing conventional techniques and allowing for sloughing of the sideway material into the trench. This will result in significant overbreak at the surface. The trench could then be backfilled with common earth backfill and conventional slurry wall technology utilized to excavate through the common earth fill. Alternatively, pre-shooting the shot rock with explosives along the alignment of the slurry trench cutoff wall could be considered. The blasting would be expected to fracture boulders, thereby facilitating standard excavation techniques. This, however, should be considered only if other means have been determined to be unfeasible.

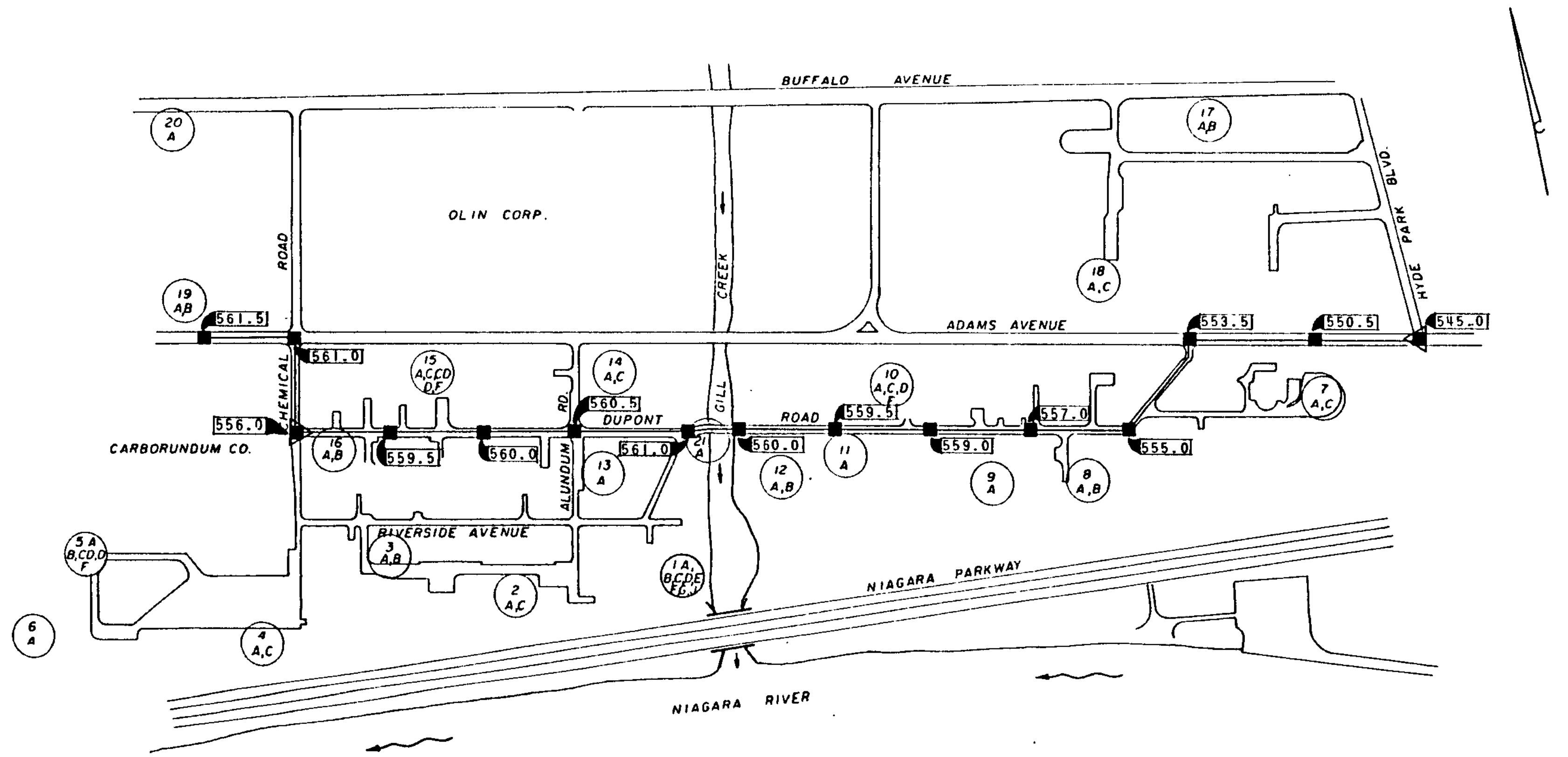
During slurry wall construction, the trench is kept filled with a bentonite and water slurry. The slurry, due to the combination of forces, acts to stabilize the trench sidewalls, thereby preventing trench collapse. It is anticipated that there is the potential for considerable slurry loss in the highly permeable areas of the shot rock. It is recommended that a soil-bentonite wall be used rather than a cement-bentonite wall, insomuch as the soil-bentonite can achieve a lower hydraulic conductivity and may be more easily controlled (via additives) to limit the amount of excessive slurry loss. For the installation at the plant site, a hydraulic backhoe is the recommended mode of excavation. Standard backhoe excavation to the depth for tracked equipment is in the range of 30 feet. The use of a backhoe to perform the excavation of the cutoff wall would probably be the most rapid and least costly technique. For a soil-bentonite backfilled trench, the general procedure is to take the excavated spoils, or alternatively, borrow material, and combine this with bentonite slurry to achieve a slump of two to six inches, and place in the trench. Probably the most important design consideration is the selection of the soil gradation to be used in the backfilling process. In some cases, at the plant site, trench soils may meet the gradation requirements. However, in areas where suspected shot rock fill are located, the gradation requirement is not likely to be achieved. As a general rule, a soil-bentonite backfill should be a well graded material with a minimum of 10 to 20 percent fines in the backfill. This would yield an effective permeability on the order of $1x10^{-6}$ to $1x10^{-7}$ cm/sec.

It would be necessary to document the permeability and permanence of the soil-bentonite backfill during final design studies. These final design permeability tests would be conducted using site groundwater as the permeant with the proposed mix design selected after engineering studies. Long-term permeability tests would determine the impact of the soil-water interaction upon the slurry wall integrity and the magnitude of any permeability deterioration. Typically this long-term test requires approximately two to three months to complete.

The important construction considerations are the blending of the backfill material to achieve the proper slump in a uniformly homogenous mix and the placement of the backfill to minimize lense development where wall leakage could occur. A typical backfilling operation procedure, after completion of the excavation, is presented diagramatically on Plate B-5.

Inasmuch as the slurry wall will be constructed at an active plant site, the connection of a cutoff wall to the surface structure is of great importance. Inherent to the nature of a slurry trench cutoff wall, some settlement and consolidation of the backfill materials would likely occur. Thus, a surface provision should be made for a clay cap subbase to prevent a seepage path from developing and to provide a safe crossing path for traffic. This subbase cap should be composed of a sufficient quantity of clay and aggregate to carry the anticipated loads or surcharge that will be exerted on the cutoff wall.

The final selection of a cutoff wall alignment should take into consideration the location of utility lines and traffic areas such that the interception of these lines and traffic pattern disruption is minimized. It should be noted that, when underground utility lines penetrate the slurry wall, additional difficulty in construction, as well as a potential path for leakage across the wall occurs. Upon selection of the final cutoff wall alignment, a detailed test drilling program should be instituted along the alignment to determine the characteristics of the overburden material that would be used for backfill and to identify potential areas where difficult construction may occur, (i.e., shot rock fill zones). In addition, the depth to rock can be better defined for estimation and construction purposes.



LEGEND:

- 17 A,B — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)
- ■ MANHOLE LOCATIONS
- PUMP MANHOLE LOCATIONS
- INVERT ELEVATION OF DRAIN TILE COLLECT SYSTEM MANHOLES

PROPOSED DRAIN TILE COLLECTION SYSTEM LAYOUT
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

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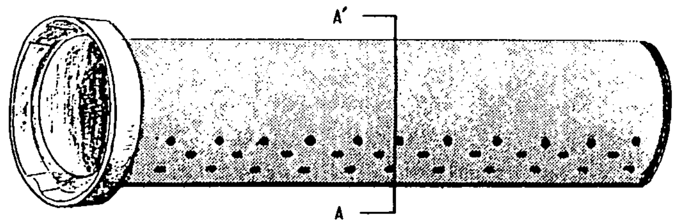
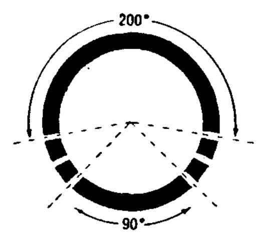
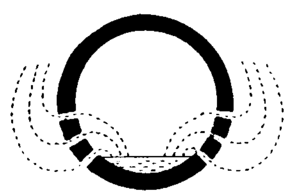
PLATE C-1



PERFORATED DRAIN TILE SECTION

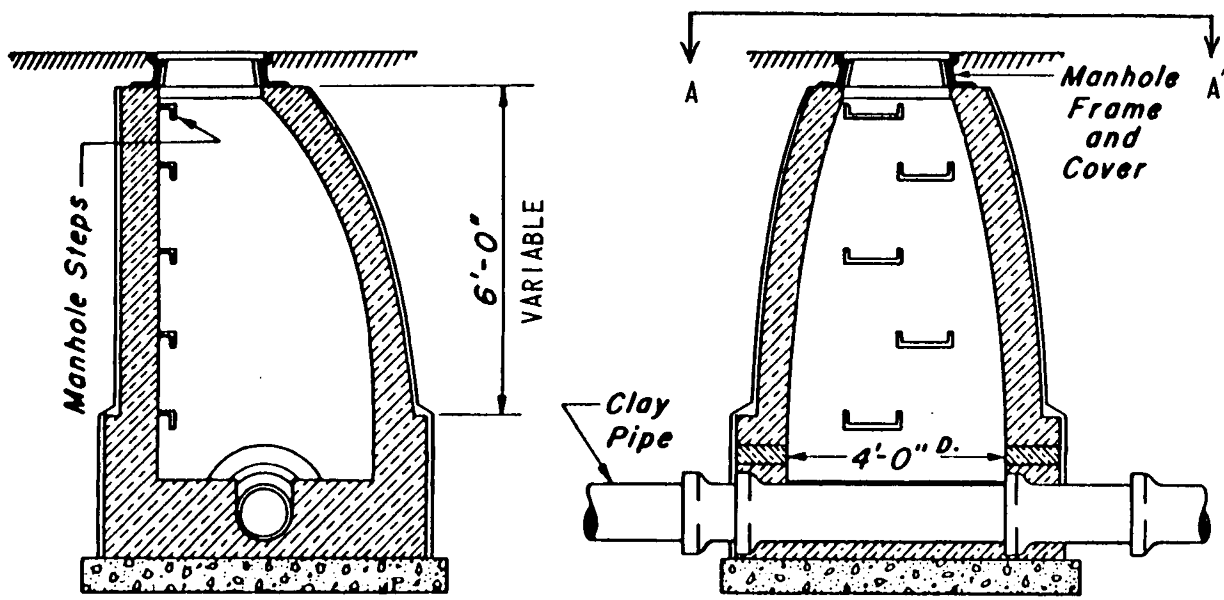




GROUNDWATER IN FLOW

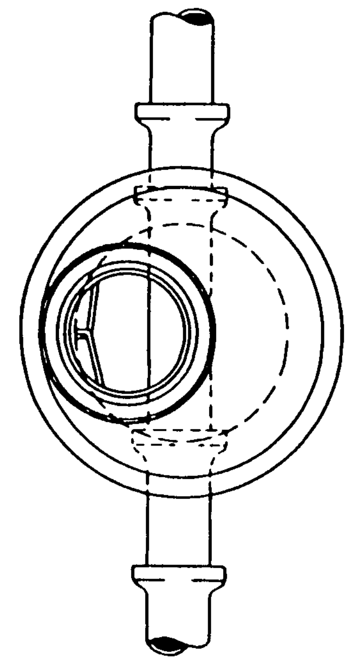
DRAIN TILE NIAGARA PLANT E.I. DUPONT DE NEMOURS & CO.		
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS, GEOLOGISTS AND ENVIROMENTAL SCIENTISTS		
Drawn By CLS	SCALE IN FEET	Date 6/26/83
Checked CRC	N.T.S.	Job 83C2236-8

PLATE C-2



VERTICAL SECTIONS

NOT TO SCALE



SECTION
A-A'

TYPICAL LINE MANHOLE
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.
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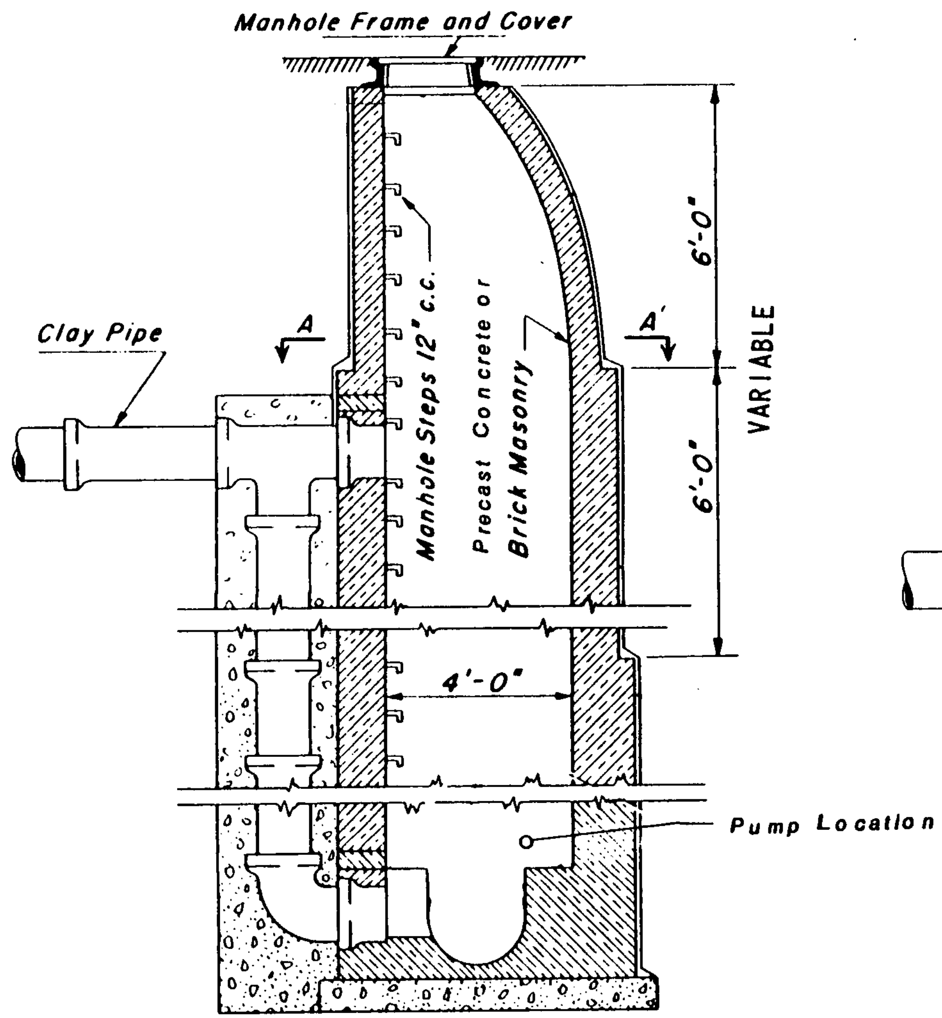
PLATE C-3



VERTICAL SECTION

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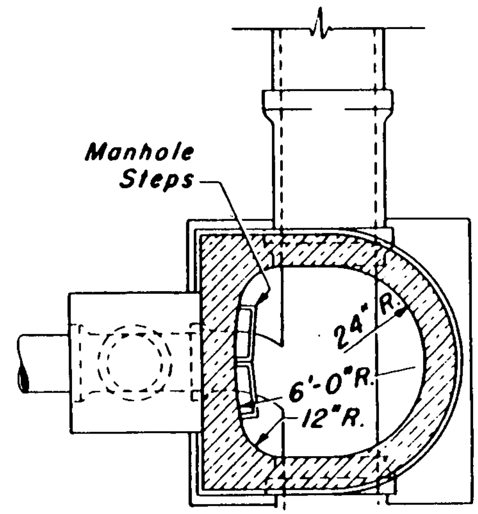
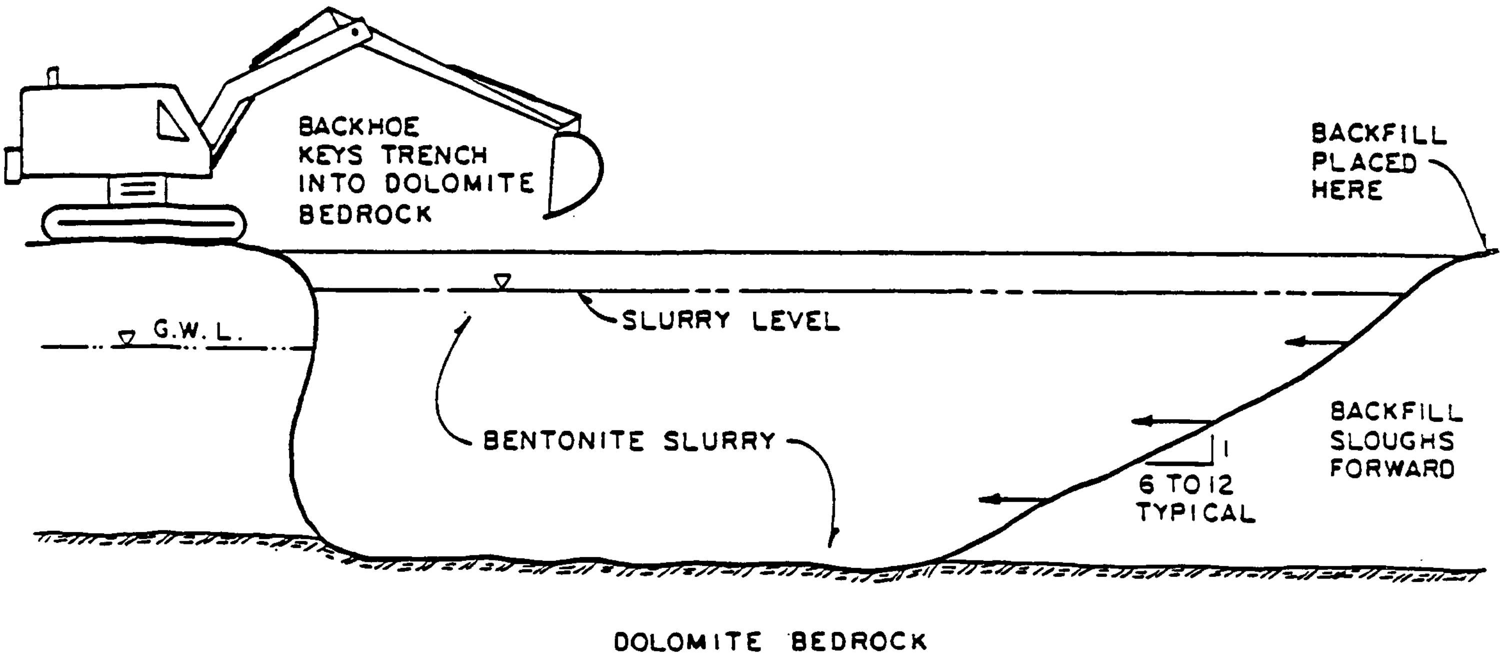


SECTION A-A'

TYPICAL DROP MANHOLE DETAIL
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.
83C2236-8

PLATE C-4



SCHEMATIC OF CUTOFF WALL CONSTRUCTION
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.
83C2236-8

PLATE C-5

#17