REPORT

TO

CITY OF ALBUQUERQUE AND NEW MEXICO UTILITIES, INC.

CONCEPTUAL PROCESS DESIGNS
TREATMENT OF PRODUCED GROUNDWATER
COORS ROAD FACILITY
SPARTON TECHNOLOGY, INC.
ALBUQUERQUE, NEW MEXICO

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For Sparton Technology, Inc.

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INTRODUCTION

The purpose of this report is to present conceptual process designs to
treat groundwater from the Coors Road Facility to produce either
potable-grade water or water containing no detectable concentrations of
any constituents. Constituents of concern include chromium, arsenic,
trichloroethene (TCE) 1, 1, 1 - trichloroethane (1, 1, 1 - TCA), and 1,
1 - dichloroethene (1, 1 - DCE). Assumed design influent concentrations
and current detection limits and Safe Drinking Water Act (SDWA) maximum
contaminant levels (MCL) are listed in Table 1.

Table 1 Groundwater Contaminant Concentrations			
Contaminant	Design Concentration (mg/L)	Detection Limit (mg/L)	Current MCL (mg/L)
Total Dissolved Solids (TDS)	1,000	ᵇ	500 *
Chromium	>0.1	0.001	0.1
Arsenic	0.01	0.010	0.05 ¹
TCE	1.00	0.0002	0.005
1,1,1-TCA	0.35	0.0002	0.2
1,1-DCE	0.07	0.0002	0.007
ᵇ Design to meet secondary standard * -Secondary standard - not enforceable ¹ -currently being evaluated, proposed MCl in 0.002 - 0.20 mg/L range			

The design concentration information given in Table 1 is an
approximation for use in arriving at the conceptual designs and first
estimates of treatment costs. If treatment to potable water standards
or to non-detection is to be explored further, more data are necessary
to arrive at definitive design conditions and more accurate system
sizing and cost estimates. For instance, the sizing of the RO system
(flux rate and recovery) is directly related to groundwater quality

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(concentrations of hardness, barium, silica, and other scale forming substances) due to scaling potential. It is anticipated that the constituents of these and other constituents will be verified by analytical testing before proceeding with a more detailed optimization and design study.

TREATMENT TO POTABLE-GRADE WATER

The general functions of the process steps used in the conceptual design are summarized in Table 2 and shown schematically on Figure 1. Major instrumentation is shown on Figures 2,3, and 4 (excluding the EVAP process). Descriptions of each process step and an opinion of probable cost are presented in subsequent sections.

Table 2 Summary of Process Functions	
Process Step	Description
Neutralization	Adjusts the pH from between 7 to 8 to approximately 5.5 to reduce scaling.
UV-1	Disinfects to control biofouling of the RO.
RO	Reduces the concentration of TDS, TOC, 1,1,1 TCA, chromium, and arsenic.
UV-2 *	Oxidizes remaining 1,1,1 TCA, TCE, and 1,1 DCE using UV and hydrogen peroxide.
ABS *	Adsorbs remaining 1,1,1 TCA, TCE, and 1,1 DCE using synthetic resin (regenerable with steam).
EVAP	Reduces reject stream from RO to wet solids and treated water.
* - either UV-2 or ABS would be used	

Neutralization
The neutralization process would adjust the pH from its current 7 to 8 units to approximately 6 units. This will reduce the scaling potential of the water entering the RO unit and serve to enhance the UV-hydrogen peroxide oxidation step (if used). As shown on Figure 1, a two-stage process is proposed for pH adjustment. This is a conservative approach since no data is available on the alkalinity of the groundwater. Low alkalinity waters would be difficult to adequately control with a

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single-stage process due to the low buffering capacity of the water (i.e., sensitivity of the water to pH change from chemical addition). Each unit can be bypassed, so one unit will always remain in service.

Each neutralization tank would have a capacity for 10 min of residence time, manufactured of fiberglass reinforced plastic (FRP) and lined with a corrosion-resistant coating. The chemical feed rates would be controlled by PLC, based on flow rate and pH.

Ultraviolet Light Disinfection (UV-1)

The UV-1 unit would provide disinfection to control biofouling of the RO membrane. As indicated on Figure 1, water would be fed into a medium-pressure, cylindrical UV chamber housing a 2-kW lamp. For redundancy, two UV chambers would be configured in parallel, each rated for 100 percent duty (such as Aquionics Model UV-1100). Each treatment chamber would be constructed of AISI Type 316L stainless steel and would provide a minimum UV dose of 30,000 microwatt-seconds/cm^2. Each unit would include a local control panel and a power module. The number of lamps in use and the lamp intensity would be controlled by a PLC, based on the measured transmittance and flow rate.

One variable that was not considered for this conceptual design was the presence of constituents that would foul the UV lamps. While the medium pressure lamps would have a self-cleaning mechanism, the frequency of the cleaning cycle would be dependent on the type of substances present. If excessive fouling occurred, an oxidation and filtration step should be evaluated prior to the UV and RO processes.

Reverse Osmosis (RO)

The RO process would reduce the concentration of dissolved material (inorganic ions, including chromium and arsenic, and silica) in the main process stream. The rejection of organics will vary with the contaminant's molecular weight and polarity. Concurrently, RO would increase the concentration of TDS in the concentrate stream.

As indicated on Figure 3, the RO feedwater would be pumped from a wetwell (10 min of residence time), pretreated by adding an antiscalant, and filtered through 10-micron cartridge filters. For redundancy, three

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RO units, with feed pumps and cartridge filter housings, each rated for 50 percent duty, would be installed on common headers, so that any combination of units could be used, with the remaining units on standby.

Each two-stage RO unit would be designed to include a high pressure (250 psi)pump, which would supply 8-inch diameter pressure vessels (the array would depend on the design flow rate), each containing seven standard 40-inch long polyamide RO elements (such as Dow BW30-8040). This system would yield a membrane flux rate of less than 10 gpd/sq ft. This flux rate is a conservatively low design value, which could be reconsidered during a more detailed optimization study; however, recent studies have found that the economic optimum is generally a low flux rate. The preliminary design is based on a recovery rate (the ratio of permeate to feed) of 75 percent, which also should be reconsidered during a detailed design phase, taking into account the actual measured ion concentrations in the water, because it is likely that a higher recovery would be achievable.

The preliminary design is based on a chromium rejection of 95 percent and an arsenic rejection of 70 percent (for As^{+3}). With a total chromium MCL of 0.1 mg/L, the RO would be capable of treating an influent containing up to 2.0 mg/L with a 95 percent rejection rate. At an influent arsenic concentration 0.01 mg/L, a 70 percent rejection rate would produce an effluent with 0.003 mg/L. Presently, the arsenic MCL is set at 0.050 mg/L. However, this limit is under review. In the latest AWWA Regulatory Update (February 14, 1996) it was noted that the proposed MCL may be lowered to the 0.002 to 0.020 mg/L range.

Alternative 1. Ultraviolet Light and Hydrogen Peroxide Oxidation (UV-2)
The UV-2 unit would remove organics by chemical oxidation with hydrogen peroxide assisted by UV light. The amount of UV energy and hydrogen peroxide is dependant on the concentration of oxidizable species, such as TOC, and the targeted effluent concentrations for the constituents of interest. Following RO treatment. a conservative estimate of the TOC concentration in the treated stream is 2.0 mg/L. The effluent limits for the three organics of interest, TCE, 1,1,1-TCA, and 1,1-DCE, were set with a 20 percent safety factor, allowing for a minimum of 0.002 mg/L. This was the approach used in the design of the potable water treatment system for South Adams County Water and Sanitation District, Colorado, which treats groundwater impacted by TCE and low levels of 1,1 DCE.

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The hydrogen peroxide would be added in an in-line mixer upstream of the UV-2 unit. The TOC oxidation reaction would yield carbon dioxide. Three medium-pressure UV chambers, in a parallel arrangement, would be provided, each rated at 50 percent duty, such as provided by Calgon Carbon Peroxidation Systems. This would provide the capability of maintaining 100 percent flow capacity with one unit out of service. Each water chamber would contain high wattage medium-pressure mercury lamps, each housed in a protective quartz sleeve. The UV chambers would be fabricated from AISI Type 316L stainless steel, each with a local control panel and power module. The number of lamps in use and the lamp intensity would be controlled by a PLC, based on the measured transmittance and flow rate.

An alternative configuration would consist of two UV chambers in parallel, each rated at 100 percent duty. A third option for TOC removal would be to supply higher power at UV-1. The UV-1 step would be enhanced with more lamps and by adding hydrogen peroxide. With this option, the UV-2 unit would not be needed, but a peroxide destruction module might be needed ahead of the RO process to prevent oxidative damage to the RO membrane. A more detailed evaluation of options should include comparison of the cost-benefit of the base case against the lower capital cost and higher operating cost (for example, the greater hydrogen peroxide use) of this option.

Alternative 2. Adsorption (ABS)

The ABS process would also reduce the organics concentration in the reclaimed water. In 1990, Rohm & Haas Company commercialized production of a synthetic resin that can be used to remove low molecular weight organics for drinking water treatment. This resin has been the subject of several articles describing its effectiveness versus GAC for organics adsorption. In these studies, the resin has been found to have a higher adsorption capacity for TCE and other low molecular weight organics, especially in the presence of other competing contaminants. One of the synthetic resins advantages is the ability to be regenerated on-site.

The adsorption process would include a minimum of two resin beds (four beds would be used for the 800 gpm design). The adsorbent beds would be designed for an empty bed contact time (EBCT) of 3 minutes. One would be in service while the other would be regenerated. Based on the influent concentrations shown in Table 1, regeneration would be required after approximately 14,500 bed volumes are passed through. With the 3 minute EBCT, one regeneration would be required monthly. Regeneration

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would be accomplished with steam, produced from a small boiler. The steam would be condensed, and the concentrated organic stream would be removed in a separator. The saturated aqueous phase from the regeneration step would be retained for shipment off-site for disposal or sent to a superloading vessel containing the synthetic resin. The water reclaimed from the superloading vessel would be sent back to the head of the plant for reprocessing.

Mechanical Vapor Recovery Evaporation (EVAP)

If no wastewater is to be discharged to the local publicly owned treatment works (POTW), the reject from the RO system and other miscellaneous wastestreams from the site would need to be removed from the site or treated further. Using a recovery of 75 percent for the RO system, there would be 25 gallons of reject water produced for every 100 gallons of water treated. With a design range of 200 to 800 gpm, the reject flow would range from 50 to 200 gallons per minute (gpm). Even at the lowest flow rate, this translates into 72,000 gallons per day (gpd) of water.

One option is to truck the reject waters to an off-site disposal point. However, at 72,000 gpd, the flow is too great for truck disposal off-site. Using a 4,500 gallon tank truck, a total of 16 truckloads of water would need to be removed from the site each day under the lowest flow design scenario. While the recovery may be increased to between 80 and 85 percent, a minimum of 10 trucks would still be required each day for off-site disposal.

Evaporation ponds are an option used in semi-arid parts of the country for disposal of brine waters. Using a net evaporation rate of 60 inches per year for the Albuquerque area, a minimum 16 acre evaporation pond would be required to handle the annual discharge from the groundwater treatment system (this amount does not take into account lower evaporation rates due to increased salinity). Due to the development in the area, an evaporative pond of this size is not considered feasible.

The last option is to utilize a mechanical or steam driven evaporative technology to reduce the amount of reject water sent to the evaporative pond. This technology is used in several industries (dairy, pulp and paper, power generation) to reduce wastewater volumes and to produce drinking water from seawater in arid areas of the world. For this application, a mechanical vapor recompression (MVR) unit was selected for the conceptual design. This process takes advantage of the

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difference in boiling points between water and the less volatile components that are left in solution. Sufficient energy is applied to the wastewater to bring it to its boiling point and to keep it boiling. Boiling occurs when the temperature of the water is such that the water vapor pressure equals the ambient pressure. Therefore, the boiling point is a function of the liquid temperature and the ambient pressure.

MVR uses a compressor to add energy into the system by compressing the steam to produce a higher temperature. The steam is passed into a heat exchanger (referred to as a vapor body) with the reject water on the other side of the tube sheet. A thin film of feed water is formed by distributing the reject water over the heat exchanger surface. This is called a falling film evaporator and is the most common type of thin film evaporator. These evaporators are characterized by high heat transfer rates which result in compact process units. As the steam cools and condenses, the reject water will vaporize, leaving the nonvolatile dissolved solids in the solution. The vaporized reject water is then pressurized for use on the other side of the tube sheet as steam. The purified water is recovered and the higher salinity water (up to 30 percent solids) is sent either to evaporation ponds or to a crystallizer. The crystallizer is similar in operation to the MVR brine concentrator, but requires a higher energy input. It can produce a slurry to be dewatered in either a centrifuge or a filter press.

Filter Press
The filter press process will concentrate the solids wastewater from the EVAP operation, yielding a filtrate that will be returned to the EVAP process and a moist solid material (dewatered to pass the paint filter test).

Opinion of Probable Cost
A budget level opinion of the probable installed cost of the treatment system to produce potable-grade water is presented in Table 3. It is important to note that these costs include equipment redundancy, as described above. The itemized costs are based on installation in 1996. A contingency of 30 percent has been added as a safety factor. The cost of land purchase, the process building, and related site development work (including piping and electrical) and the cost of design and contract document preparation have not been included. A cost of approximately 10 to 15 percent of the construction cost would be appropriate for the land/building/site development. A similar cost range would be appropriate for the design/construction documents

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preparation. If this approach is taken further, a pilot study is recommended to confirm the assumptions included in the design.

Table 3. Budgetary Cost Opinion			
Item	Probable Installed Cost, $		
	200 gpm	400 gpm	800 gpm
Neutralization	$110,000	$150,000	$210,000
UV-1	$40,000	$60,000	$80,000
RO	$430,000	$740,000	$1,300,000
UV-2	$800,000	$1,500,000	$2,700,000
ABS	$490,000	$1,080,000	$1,480,000
EVAP	$970,000	$1,510,000	$2,110,000
Chemical Feed	$40,000	$60,000	$90,000
Filter Press	$50,000	$50,000	$70,000
30% Contingency	$650,000	$1,100,000	$1,600,000
Totals (*)	$2,780,000	$4,750,000	$6,940,000
(*) - totals include lowest cost of UV-2 and ABS processes			

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Annual operating cost has also been estimated and itemized in Table 4.
These costs include depreciation/replacement cost of equipment.

Table 4 Annual Operating Costs			
Item	Plant Flow (gpm)		
	200 gpm	400 gpm	800 gpm
Maintenance/ Depreciation	$278,000	$475,000	$694,000
Energy*			
UV-1 ($/yr)	$7,533	$15,067	$30,135
RO ($/yr)	$39,310	$78,420	$163,373
MVR ($/yr)	$598,483	$1,179,885	$2,342,687
Chemical/Equipment Replacement			
Ambersorb ($/yr)	$14,444	$38,308	$59,032
RO ($/yr)	$50,080	$100,160	$200,320
Filter Press ($/yr)	$32,782	$65,563	$131,127
Disposal**			
Hazardous Landfill ($/yr)	$658,912	$1,317,823	$2,635,646
Total Costs	$1,679,544	$3,270,226	$6,256,320

*   Energy Costs are calculated using a charge of $0.10 per kWh and assume 24 hour, 365 day operation.
**   Hazardous material disposal cost based on $200 per ton landfill charge (per Chemwaste, Phoenix)

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Alternative Designs

There are two important issues to be discussed in the consideration of this conceptual design. Both of these issues have the potential to substantially reduce the costs of treatment.

- Possibility of discharge to sanitary sewer.

- Elimination of reverse osmosis system for lower metals concentration.

Discharge to Sanitary Sewer. For purposes of developing the conceptual design it has been assumed that no discharge of wastewater would be allowed from the site. If this assumption was removed to allow the site to discharge the reject from the RO system as wastewater to the sanitary sewer system, the costs for the EVAP process would be eliminated. Depending on the local pretreatment limits imposed by the POTW, some additional pretreatment may be required for metals or organics removal. A more detailed study would be required to determine exact pretreatment requirements. However, assuming that chromium and arsenic are both to be removed from the reject water, several vendors can provide electrochemical precipitation processes that would produce acceptable treated water quality for discharge to the sanitary sewer. For instance, Andco Environmental Systems has provided process equipment for both chromium and arsenic removal from impacted ground and surface waters. These systems would then produce a chemical solid for dewatering and disposal at a much lower capital and operating cost than the EVAP process. If organics discharge to the sanitary sewer (because of concentration through the RO) is the limiting factor, the UV-2 or the ADS processes could be installed prior to the RO to produce an acceptable quality of water for reclamation and discharge. This is an option that could be explored to reduce system costs.

Elimination of RO Process. In the conceptual design, the RO process is included to reduce the chromium and arsenic to their current drinking water MCLs and to reduce TDS to its secondary MCL (SMCL) of 500 mg/L. If the groundwater can be drawn from another portion of the aquifer that has acceptable concentrations of these three constituents, the RO

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process could be eliminated. The process design would then consist of one of the following options:

<u>UV-Hydrogen Peroxide</u>   <u>Adsorption</u>
(possible iron removal)   (possible iron removal)
pH adjustment   cartridge filtration
UV-H_2O_2 oxidation   adsorption and regeneration
                             UV disinfection

This approach could substantially reduce capital and operating costs by over 50 percent. Amortization cost analysis for an assumed 30- to 100-yr operating period indicate treatment costs of $7 to $8 per 1,000 gallons treated. Wastewater discharges to the sanitary sewer could be eliminated with the addition of an evaporation pond for any wash water used on-site.

TREATMENT TO NO-DETECTABLE CONCENTRATION

As was noted in the previous section, the constituent concentrations given in Table 1 are approximations for use in arriving at the conceptual design and first estimates of treatment costs. If treatment to non-detection water standards is to be explored further, more data are necessary to arrive at definitive design conditions and more accurate system sizing and cost estimates.

The general functions of the process steps used in the non-detect conceptual design are summarized in Table 5. The design is a modified version of the potable-grade water treatment process previously described and shown on Figures 1 through 4. Modifications are shown in bold. Descriptions of the modified processes and their effect on probable cost are presented in subsequent sections.

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Table 5 Summary of Process Functions	
Process Step	Description
Neutralization	Adjusts the pH from between 7 to 8 to approximately 5.5 to reduce scaling.
UV-1	Disinfects to control biofouling of the RO.
RO	Reduces the concentration of TDS, TOC, 1,1,1 TCA, chromium, and arsenic.
ABS-1	Adsorbs remaining 1,1,1 TCA, TCE, and 1,1 DCE using synthetic resin (regenerable with steam).
ABS-2	**Granular Activated Carbon (GAC) serves as buffer for organics during breakthrough of synthetic resin.**
EVAP	Reduces reject stream from RO to wet solids and treated water.
IX	**Demineralizer for removal of chromium below detection limits**
STAB	**Stabilize corrosive tendencies of demineralized water with soda ash**

Adsorption (ABS-2)

The ABS-2 process would serve as a buffer to the ABS-1 process to ensure that the treated water organic concentration remains below the detection limit. The Rohm & Haas synthetic resin would be used in ABS-1. Granular activated carbon would be used in ABS-2. The synthetic resin's higher adsorption capacity for TCE and other low molecular weight organics and its ability to be regenerated on-site make it appropriate for use as the main adsorption step. The effluent of the ABS-1 would be monitored daily for the organics of concern to be detected. When they are detected, the resin beds would be regenerated. For the period of time between the organics appearing in the effluent of ABS-1 and regeneration, the GAC would serve as the adsorption step to reduce the concentrations sent to the public to below detectable levels.

The ABS-2 process would consist of a single bed with the diameter and loading being dependent on the selected size of the system. The GAC beds would be designed for an empty bed contact time (EBCT) of 10 minutes. In a previous study for South Adams County, Colorado, full scale data of a GAC system adsorbing 1,1, DCE showed a carbon usage rate of 0.17 pounds per 1,000 gallons treated with 1,1, DCE concentrations less than 0.007 mg/L. Assuming this loading rate for a period of two days per month during ABS-1 regeneration, the carbon usage rate would

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range from 1,200 to approximately 9,400 pounds per year for liquid flows of 200 and 800 gpm respectively. The spent carbon would be regenerated off-site under contract with fresh carbon being used for the replacement.

Ion Exchange (IX)

The preliminary design is based on a chromium rejection of 95 percent and an arsenic rejection of 70 percent (for As^{+3}). With a chromium MCL of 0.1 mg/L, the RO would be capable of treating an influent containing up to 2.0 mg/L with a 95 percent rejection rate. Thus, to meet detection limits of chromium at 0.001 mg/L with this influent chromium concentration, an additional step would be required. To meet the non-detectable limits for chromium consistently (0.001 mg/L), it is proposed to demineralize the water processed through the RO step using ion exchange. The RO would serve the purpose of lowering the TDS to reduce the loading on the IX resin. By doing this, the IX system could be provided on a leased basis to reduce the operator involvement. However, the IX system would require column studies to be performed to determine treatment effectiveness due to the low level of chromium desired in the effluent. These column studies would also be used to arrive at an estimate of bed life and regeneration frequency.

Stabilization (STAB)

Due to the low TDS of the processed water, soda ash would be added to increase the alkalinity and reduce the corrosive tendencies of the water sent to the distribution system. The chemical feed facility would be based on feeding a set dosage of soda ash to provide an alkalinity of more than 15 mg/L.

Opinion of Probable Cost

The effects of these changes on the probable installed cost of the treatment system are presented in Table 6. The itemized costs are based on installation in 1996. A contingency of 30 percent has been added as a safety factor. As previously noted, the cost of the process building and related site development work (including piping and electrical) and the cost of design and contract document preparation have not been included. A cost of approximately 10 to 15 percent of the construction cost would be appropriate for the land/building/site development. A similar cost range would be appropriate for the design/construction documents preparation. If this approach is taken further, a pilot study is required to determine the efficiency of meeting the 0.001 mg/L chromium limit consistently.

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	Table 6 Budgetary Cost Opinion		
	Probable Installed Cost, $		
Item	200 gpm	400 gpm	800 gpm
Previous Totals (Potable-Water System)	$2,780,000	$4,750,000	$6,940,000
ABS-2	$80,000	$130,000	$140,000
IX	$180,000	$350,000	$600,000
Stabilization	$15,000	$15,000	$20,000
30% Cont.(*)	$82,500	$148,500	$228,000
Totals	$3,137,500	$5,393,500	$7,928,000
(*) - on modifications only			

Annual operating costs are given in Table 7.

	Table 7 Annual Operating Costs		
	Plant Flow (gpm)		
Item	200 gpm	400 gpm	800 gpm
Previous Totals (Potable-Water System)	$1,679,544	$3,270,226	$6,256,320
Carbon Replacement ($/yr)	$1,500	$3,900	$11,500
Ion Exchange ($/yr)	$230,000	$430,000	$870,000
Stabilization	$5,000	$5,000	$7,500
Maintenance/ Depreciation	$35,750	$64,350	$98,800
Total Costs	$1,951,794	$3,773,476	$7,244,120

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Attachments

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RESIDUAL
(OFF-SITE DISPOSAL)

ABS

H_2SO_4

H_2O_2

RAW
WATER

NEUTRALIZATION → UV-1 → RO → UV-2 → POTABLE WATER

METALS
WASTEWATER

EVAP

RECLAIMED
WATER

CHEMICAL ADDITION

RECLAIMED
WATER

FILTER PRESS

WET SOLIDS
(OFF-SITE DISPOSAL)
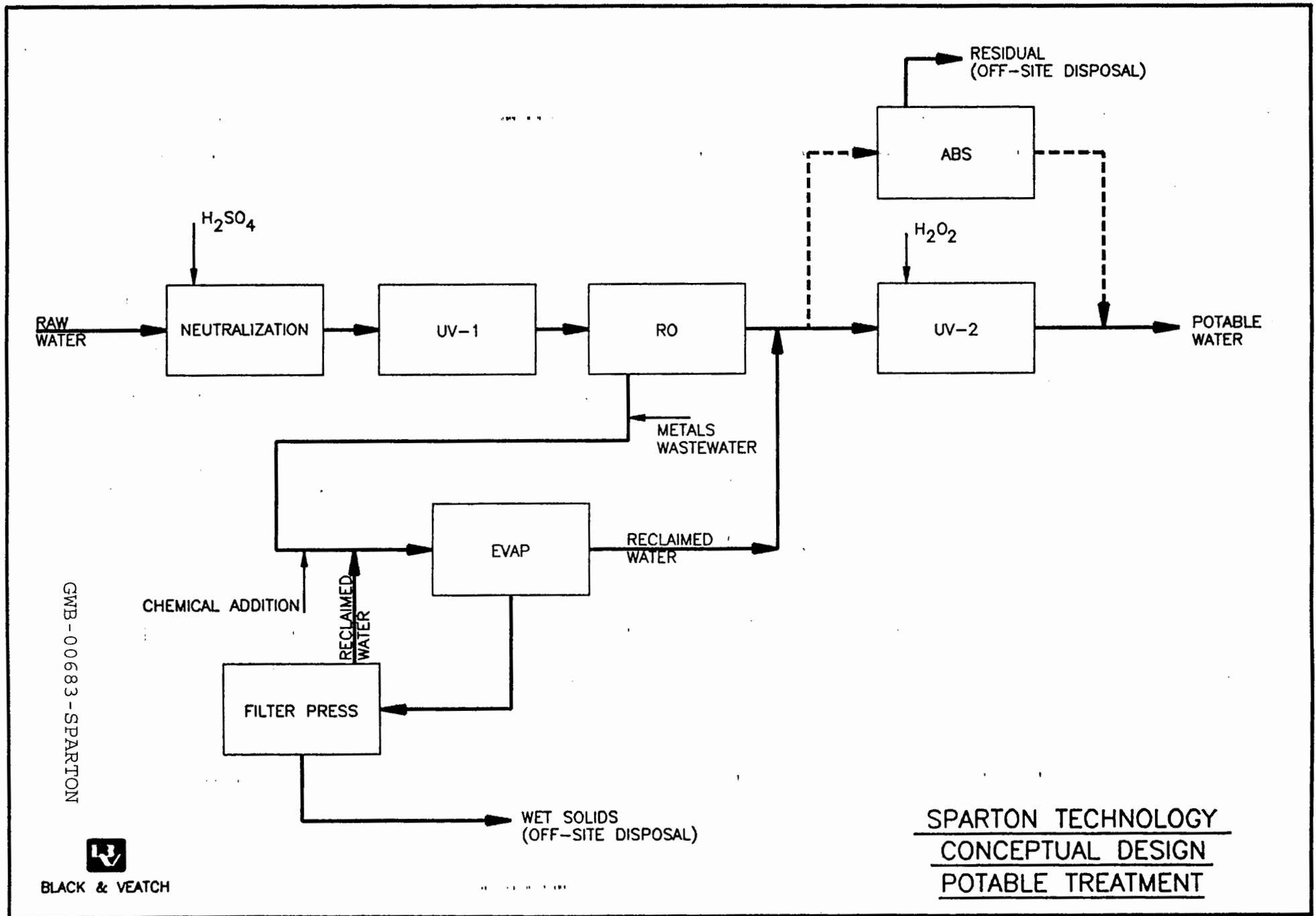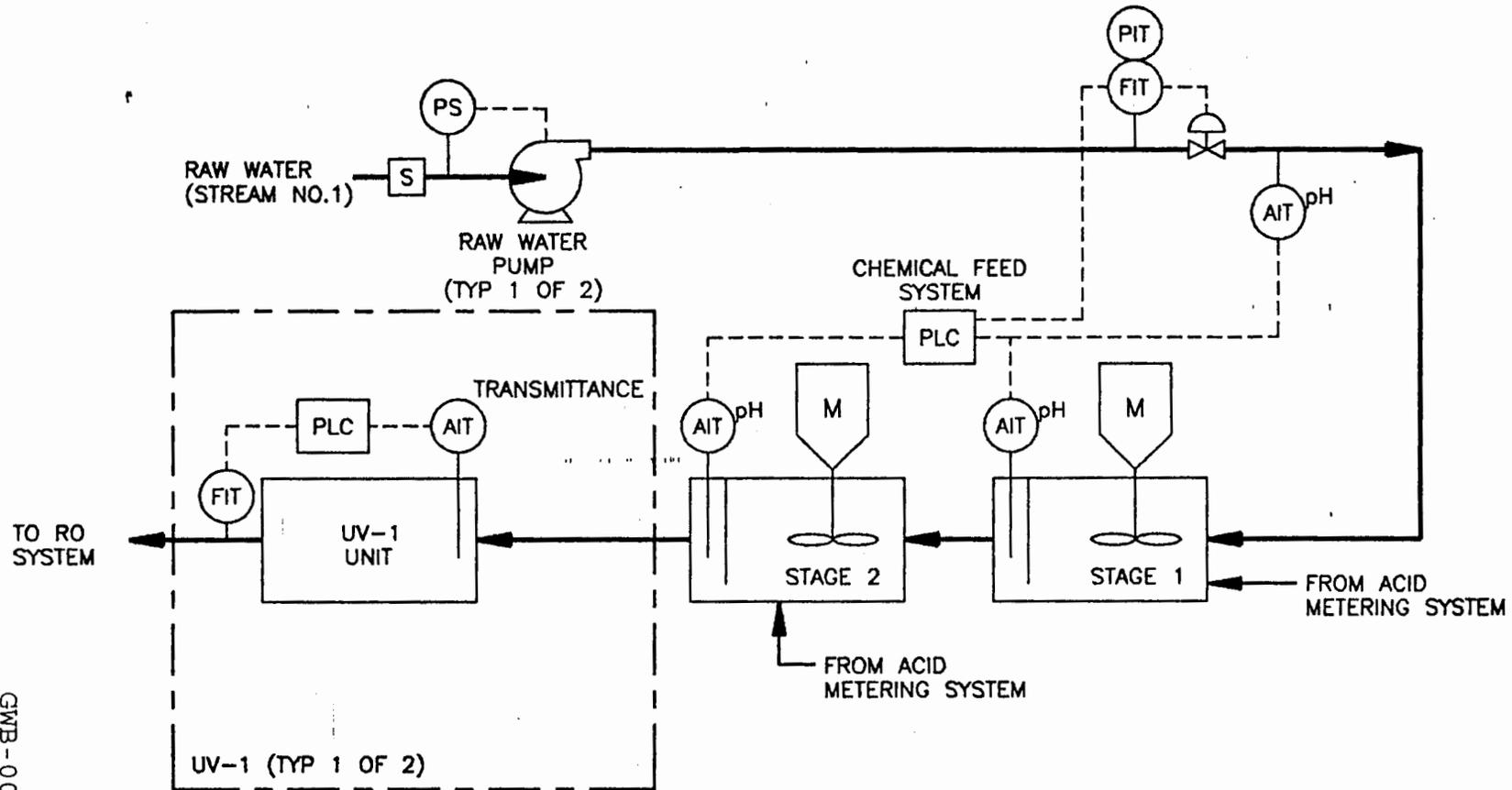
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SPARTON TECHNOLOGY
CONCEPTUAL DESIGN
POTABLE TREATMENT

Figure 1

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SPARTON TECHNOLOGY
CONCEPTUAL DESIGN
NEUTRALIZATION, UV-1

Figure 2

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SPARTON TECHNOLOGY
CONCEPTUAL DESIGN-RO

Figure 3

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TRANSMITTANCE — — — H₂O₂ FEED SYSTEM

RO PERMEATE FROM RO SYSTEM

UV-2 UNIT

FROM H₂O₂ METERING SYSTEM

UV-2 (TYP 1 OF 2)

H_2O_2 FEED SYSTEM

POTABLE WATER

--- OR ---

RO PERMEATE FROM RO SYSTEM

ORGANICS / STEAM

CONDENSER

SEPTAGE

ORGANICS

ABS UNIT

ABS UNIT

ORGANICS / STEAM

SUPER LOADING VESSEL

TO NEUTRALIZATION

STEAM BOILER

RECLAIMED WATER

POTABLE WATER

ABS (TYP 1 OF 2)

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CONCEPTUAL DESIGN
UV-2 OR ABS

Figure 4