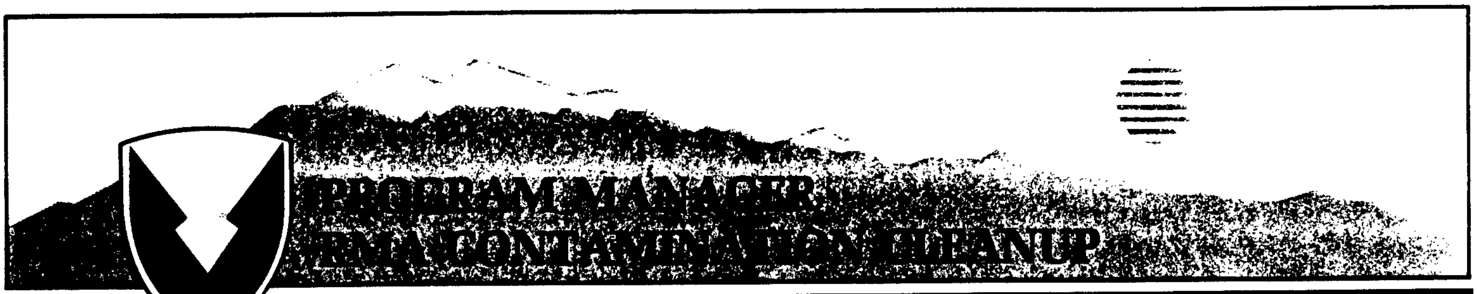

PROGRAM MANAGER
RMA CONTAMINATION CLEANUP

U.S. ARMY
MATERIEL COMMAND

— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

COMPREHENSIVE MONITORING PROGRAM

Contract Number DAAA15-87-0095

FINAL TECHNICAL PLAN
OCTOBER 1989

Version 3.1

SURFACE WATER

R.L. STOLLAR & ASSOCIATES, INC.
Harding Lawson Associates
Ebasco Services Incorporated
DataChem, Inc.
Enseco-Cal Lab
Midwest Research Institute

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THE PURPOSE OF THE SURFACE WATER COMPREHENSIVE MONITORING PROGRAM IS TO MONITOR SURFACE WATER QUANTITY AND QUALITY IN ORDER TO VERIFY THE DATA COLLECTED AND THE CONCLUSIONS DRAWN IN THE REMEDIAL INVESTIGATION. THIS OBJECTIVE WILL BE ACHIEVED BY MONITORING 1) SURFACE WATER QUANTITY AND QUALITY, 2) STORMFLOW QUANTITY AND QUALITY, AND 3) SEDIMENT TRANSPORT.

SECTIONS OF THIS DOCUMENT PROVIDE INFORMATION ON:
1. PROGRAM OBJECTIVES AND SUMMARY
2. SURFACE WATER FEATURES AND PREVIOUS INVESTIGATIONS
3. TECHNICAL PROGRAM INCLUDING NECESSARY EQUIPMENT, MONITORING LOCATIONS, WORK STRATEGIES, MONITORING METHODS
4. LABORATORY ANALYSIS PROGRAM
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SURFACE WATER

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U.S. ARMY PROGRAM MANAGER'S OFFICE FOR
ROCKY MOUNTAIN ARSENAL

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1.0 INTRODUCTION

1.1 Program Objectives

The purpose of the Surface Water Monitoring Element of the Comprehensive Monitoring Program (CMP) at the Rocky Mountain Arsenal (RMA) is to monitor surface water quantity and quality in order to verify the data collected and the conclusions drawn in the Remedial Investigation (RI) Program. These objectives will be achieved by monitoring:

- o surface water quantity;
- o surface water quality;
- o stormflow quantity and quality; and
- o sediment transport.

In addition to verifying the results of the RI Program, the results of this monitoring program will be used to:

- o expand the available data for, and to monitor the implementation of, the surface water management program at RMA;

- o monitor the effect of interim remedial actions on the surface water system and to expand and maintain the data base which will be used to judge the effect of future remedial actions at RMA on surface water flow and quality; and

- o continue to provide a quality data base using USATHAMA certified or equivalent quality certified methods.

1.2 Program Summary

During the first year of the CMP, the existing RMA stream flow and quality monitoring network, which has been employed in the RI (Task 44) monitoring program, will be maintained. It will only be supplemented to a limited extent, in the surface water element of the CMP. After the first year of operation of the CMP, recommendations for modifying or upgrading the monitoring system may be made.

Stream stage and instantaneous discharge will be measured at each of the surface water monitoring stations which are described in Section 2.2.1. In addition, water quality will be monitored at the existing sampling stations. At these locations, the samples will be analyzed for the set of target analytes described in Section 4.1 and selected samples will be screened using gas chromatography/mass spectroscopy (GC/MS) techniques. This screening approach will be used to identify which constituents are migrating onto and off of RMA via surface water flows, and to supplement the measurement of the target analytes on the Arsenal.

Stream sediment samples will be collected along First Creek and analyzed for select target compounds to enable an evaluation of suspended and bed load movement, and associated contaminant migration. First Creek was selected as the location for the monitoring of sediment transport as this creek is the only perennial stream which traverses RMA and is the most likely pathway by which sediments could be transported off of the Arsenal. Following the assessment of sediment transport in First Creek, other areas may be monitored if warranted by the information obtained from this program.

The relationship between surface water and ground water will be examined at two key locations on RMA. On First Creek, recharge to or gains from the ground water will be monitored through a seepage study which will measure changes in baseflow along the stream. The relationship between the lakes and the underlying ground water will be monitored by measuring the elevation (stage) of the lakes and the potentiometric elevation in adjacent shallow wells, as well as compiling relevant meteorological data (evapotranspiration and precipitation).

Continued monitoring of the surface water system under the CMP will be conducted under four situations:

- seasonal monitoring of water flow and quality;
- high event monitoring of peak flows and associated water quality;
- monitoring of those portions of the RMA surface water system that will be affected by the surface water management program; and
- monitoring of the influence of remedial actions on surface water flows, quality and sediment loading.

2.0 BACKGROUND INFORMATION

2.1 Surface Water Features at RMA

RMA lies within the South Platte River drainage basin. Surface water on RMA flows within several smaller drainage basins that are tributary to the South Platte; First Creek, Second Creek, Sand Creek, and Irondale Gulch (Plate 2.1-1). Superimposed on these natural drainage basins are man-made structures which have modified the surface water system. These structures include diversion ditches, the major lakes, the basins developed to retain waste water and storm runoff, as well as many culverts, sewers and other control structures. The following section briefly describes the principal surface water features on RMA. This information provides a framework for the subsequent description of the surface water monitoring programs and network at RMA, and a preliminary evaluation of the adequacy of the existing monitoring network.

2.1.1 Drainage Basins

The following sections describe the drainage basins on RMA which are located on Plate 2.1-1.

First Creek Drainage

First Creek Basin originates in Arapahoe County, Colorado, about 20 miles east of downtown Denver. The basin is approximately 26 miles long and varies from one to four miles in width (Wright Water Engineers, Inc., 1988). The basin drains 27 square miles upstream of RMA and approximately 12 square miles on RMA. Land use upstream of the Arsenal is primarily agricultural (U.S. Army Corps of Engineers, 1983a). Soil infiltration rates in the southeast portions of the First Creek Basin are low to moderate, increase at the southeastern boundary of RMA, and are moderate within RMA boundaries. Off-post infiltration rates are expected to change with the continued development associated with the new airport and the Green Valley Ranch, which are located upgradient of RMA.

First Creek flows approximately 24 miles northwesterly from its source to its confluence with O'Brian Canal about 0.5 miles north of the northern boundary of RMA. This includes about 5.5 miles of channel on RMA. There are seven road or railroad crossings over First Creek within RMA. The passages primarily consist of culverts beneath the roadways and have limited flow capacities (U.S. Army Corps of Engineers, 1983b). The average thalweg slope is 31 feet per mile upstream of RMA and 26 feet per mile across RMA. The First Creek channel is fairly straight within RMA, with only minor bends. This is due partly to the channel straightening done in the northwest portion of Section 5 and on the east side of Section 24 following a major flood in 1973 (U.S. Army Corps of Engineers, 1983a).

The channel capacity of First Creek as it enters RMA is about 250 cubic feet per second (cfs) and is about 300 cfs downstream of the sewage treatment plant outfall at the north boundary (Resource Consultants, Inc., 1982).

The topography of the First Creek Basin within RMA is gently undulating with low hills along the left and right overbanks. As First Creek traverses RMA, several tributaries have the potential of contributing to its flow. Runoff from the old Section 6 Toxic Storage yard is drained into First Creek by two drainage ditches (Ebasco Services, Inc., 1988b). The first well defined tributary, an old overflow for Upper Derby Lake, enters First Creek in Section 6. Under normal flow conditions, this tributary no longer carries water from Upper Derby Lake.

First Creek then flows through four small detention or retention dams in Section 31. Prior to their failure, the combined available storage behind these dams was approximately 150 acre-feet (U.S. Army Corps of Engineers, 1983a). The next tributaries join First Creek in the northwest corner of Section 31 and drain the Toxic Storage Yard in Section 31. The North Plants area is drained by a tributary which joins First Creek in the central-western portion of Section 30. During high flow events, water from Sand Creek Lateral can enter First Creek. In the northeast corner of Section 24 effluent from the Sewage Treatment Plant enters First Creek. Just before First Creek crosses the north boundary it intercepts a small channel which drains overflow from the North Bog.

North Bog is a 2.7 acre (117,000 ft^2) body of water located in the northwest quarter of Section 24. During high flow events water from First Creek flows into the bog. Since 1983 North Bog has been used as a natural recharge basin for treated ground water from the North Boundary Containment System (Ebasco Services, Inc., 1988a).

Second Creek Drainage

The northeast half of Section 20 is within the Second Creek Basin. The basin has a total drainage area of 20.6 square miles, of which only 0.6 square miles are within RMA. Upstream of RMA Second Creek Basin is 9.1 miles in length. The width of the basin varies from one to nearly 3.5 miles and the main channel length is 12.3 miles. Less than 1,000 feet of the main stream channel crosses RMA. Drainage is to the northwest (Resource Consultants, Inc., 1982).

The soils of the Second Creek Basin have low infiltration rates upstream of RMA where land is primarily used for agriculture. Soils on RMA have low to moderate infiltration rates. The more incised and sinuous nature of the channels in this drainage, in comparison with the First Creek, may be attributed to the lower infiltration rates exhibited by the soils in the Second Creek drainage (Resource Consultants, Inc., 1982). That portion of Section 20 which lies within the Second Creek drainage has been used as a buffer zone for Arsenal operations.

Sand Creek Drainage

Sand Creek drainage includes 2.2 square miles in the southwest area of RMA. At its nearest point, Sand Creek is approximately 1.2 miles from the southwest boundary of RMA. The lack of any major channelized flow within RMA has been attributed to the high infiltration rates of the soils in this area (Resource Consultants, Inc., 1982). Many natural depressions in the basin intercept runoff, so that surface flow tends to be local. In the event of an extreme precipitation event runoff could progress from one depression to another in a northwesterly direction, finally exiting on RMA's western boundary (Resource Consultants, Inc., 1982).

The Sand Creek drainage is traversed by the Stapleton International Airport runways and drainage system, which extend into Section 10 adjacent to RMA. Runoff from the airport and the Sand Creek drainage is partially intercepted by the Havana Interceptor which returns the flows to RMA. A detailed hydrologic analysis of the drainage in this area was performed as part of the airport expansion studies (Wright-McLaughlin Engineers, 1969).

Land use upstream from RMA in Sand Creek Basin is dominated by Stapleton International Airport and related facilities. Prior to construction of the north-south runway, Sections 9, 10, and 33 were used as buffer zones for Arsenal operations. Section 4 includes two landfills and an administrative area. A U.S. Post Office installation and Denver Water Treatment facility are now located in Section 9 (Plate 2.1-1).

South Platte Drainage

Approximately 3.4 square miles in the northwest corner of RMA drain toward the South Platte. This subcatchment is identified in recent Urban Drainage and Flood Control Studies as direct flow (DF) area 55. The subcatchment is bounded by the Irondale Gulch drainage to the southwest, the Sand Creek Lateral to the east and southeast, and First Creek to the northeast. Basin F is isolated from surface runoff and is within the South Platte drainage area. This disposal basin occupies a natural topographic depression with surrounding elevated embankments designed to contain liquid waste. Construction activities associated with the Basin F Interim Response Action initiated in 1988 have altered the original basin topography. Evaluation of the surface-water runoff characteristics in the new Basin F area will be undertaken as part of the Surface Water CMP. Monitoring strategy will be included as an addendum to the Surface Water Annual Report.

Soil infiltration rates are high in the central and southwest portion of the subcatchment, moderate in the west, southeast, and north-central areas, and low in the north-northeast where bedrock is near the surface (Resource Consultants, Inc., 1982). Due to the low infiltration rates, more overland flow is expected in the north-northeast area of this subcatchment. The flow direction would be to the north and west boundaries of RMA.

Irondale Gulch Drainage

The Irondale Gulch drainage originates at the intersection of Interstate 70 and East Colfax Avenue. It drains 11.5 square miles upstream of RMA and 6.5 square miles of RMA. Flow is to the northwest. Sand Creek Lateral intercepts runoff from the southwestern area of South Plants, downgradient of the diversion structure at the Lower Lakes, and flows north out of the Irondale Gulch drainage. The drainage area consists of undulating topography with low rolling hills. Vegetation is mainly grasses with some scattered trees along the lakes and channels and in some low areas (U.S. Army Corps of Engineers, 1983c).

Four lakes and several other impoundments are located in the Irondale Gulch Basin on RMA. The Havana and Peoria Interceptors, North and South Uvalda Street Interceptors, and Highline Lateral all flow from south of RMA to the lakes. Upstream drainage patterns have been modified by the construction of subdivisions, channelizations, and storm drains. Upstream development is composed of light industrial development, urban residential development, and open range land. Urban development covered 32% of the basin in 1983 and was expected to increase (U.S. Army Corps of Engineers, 1983a).

Soil infiltration rates are high throughout most of the Irondale Gulch Drainage Basin except southeast of the lakes on RMA. Infiltration rates are reported to be moderate in this area (Resource Consultants, Inc., 1982). Natural drainage channelization is poorly defined or lacking over most of Irondale Gulch Basin on RMA in part due to the moderate to high soil infiltration rates.

2.1.2 Diversion Channels

Flows within the natural drainage basins on RMA have been greatly modified through the construction of a number of diversion (laterals) and drainage (interceptors) channels. The most significant of these man-made channels are described below.

Peoria Interceptor, Havana Interceptor, and Havana Pond

The Havana and Peoria Interceptors drain industrial and residential areas south of RMA, flow to the north-northeast across Section 11 on RMA, and terminate in the Havana Pond. The pond contains 5 acre-feet of water covering one acre during normal pool storage. In the past, water levels were kept low to allow for additional storage capacity of flood events. The pond could hold 79 acre-feet of water covering 22 acres if filled to the crest of the embankment (U.S. Army Corps of Engineers, 1983c). Overflow and discharge are released to Sand Creek Lateral which flows to the north (Wright Water Engineers, Inc., 1988).

Uvalda Interceptor

The Uvalda Interceptor is a controlled channel which flows north 1.2 miles from the Montebello subdivision south of the RMA boundary to a diversion box at the Highline Lateral. From this point, flow from the Uvalda Interceptor and Highline Lateral may be diverted to either Upper or Lower Derby Lake (Ebasco Services, Inc., 1987c). The Uvalda Interceptor has a discharge capacity of 1,200 cfs at the south RMA boundary and 600 cfs near 6th Avenue (U.S. Army Corps of Engineers, 1983a). The average channel bottom width is seven feet, and the average depth of the channel is eight feet (Larsh, 1969).

Highline Lateral

The Highline Lateral, which originates south-east of RMA, flows from the south border of RMA at the southwest corner of Section 8 to the diversion channel just south of Upper Derby Lake in Section 1. The lateral is used as an intake canal to deliver water from Lake Cheesman. Flow within the Highline Lateral is periodic, based on seasonal availability and water rights controlled by RMA. The discharge capacity of the lateral is 75 cfs. The average ditch bottom width is eight feet, and the average depth of the ditch is four feet (U.S. Army Corps of Engineers, 1983a).

Sand Creek Lateral

The Sand Creek Lateral originates in the Irondale Gulch drainage, receiving flows from Havana Pond. The lateral leaves the Irondale Gulch drainage in the southern portion of Section 35, flows northeast through the South Platte drainage, and terminates at First Creek in the First Creek drainage. The Sand Creek Lateral intercepts surface flow within the Irondale Gulch and South Platte drainages and is therefore considered to have a catchment area.

Normally, water from the Havana Pond is released to the Sand Creek Lateral only after large storm events. Flow in Sand Creek Lateral could also originate from the South Lakes if water was released into the Lateral from Lower Derby Lake, rather than being diverted into Ladora Lake. Surface drainage and runoff from the southwestern area of the South Plants are intercepted by Sand Creek Lateral downgradient of the diversion structure.

Within the South Platte drainage, a channel is located near the eastern boundary of the catchment. The channel originates near the Lime Setting Ponds in Section 36. Water within this channel flows under Sand Creek Lateral and into the South Platte drainage.

The Sand Creek Lateral catchment within the South Platte drainage also contains a reservoir in the eastern side of Section 35 which is currently dry. This reservoir was designed and constructed as a basin which was to receive caustic waste from the South Plants area although it was never used for this purpose. The caustic waste basin has no formal outlet. Consequently, it is probable that no surface flows escape the caustic waste basin, so that all precipitation is either stored, evaporated, transpired, or infiltrates.

Flow in the Sand Creek Lateral can be diverted to Basin C and was diverted to Basin C from 1953 to 1956. Aqueous waste overflows from Basin B were directed into the Sand Creek Lateral and then diverted to Basin C during this period, until new chemical sewer lines to Basin F were functional in December of 1956.

2.1.3 RMA Lakes

Six lakes have been constructed on RMA. Four were utilized as part of the Process Water System for the South Plants complex. These lakes are supplied by a number of the diversion channels and, in turn, probably play a significant role on the relationship between surface water and ground water at RMA.

The Process Water System was installed in 1942 during the initial construction of the South Plants complex. The original system, which operated until 1964, was used to remove heat from the manufacturing process in South Plants and to provide water for fire protection. The system was composed of four lakes, Upper Derby, Eastern Upper Derby (an extension of Upper Derby Lake), Lower Derby, and Ladora, which were used for storage and cooling of process water; a distribution system which pumped water from Lake Ladora to the plant buildings; and a system which returned water to Upper or Lower Derby Lake.

Eastern Upper Derby Lake

Eastern Upper Derby Lake is located in the southwest quarter of Section 6. The lake has a clay lined bottom and covers about 15 acres. The lake receives inflow from a small drainage at its eastern extremity. The Upper Derby Lake Overflow ditch exits from the north edge of the lake and flows northeast towards First Creek. In the spring and early summer months the lake can be full from surface runoff and inflow through a culvert from Upper Derby Lake. During the late summer, fall and winter months when surface runoff is low, the lake is marshy or dry (Ebasco Services, Inc., 1987b).

Upper Derby Lake

Upper Derby Lake is located in the southeast quarter of Section 1, immediately west of Eastern Upper Derby Lake. Upper Derby Lake was constructed after Lower Derby Lake to increase the volume of water in storage for the Process Water System. The lake bottom was originally lined with clay to reduce leakage, although it has since been dredged. The surface area of the lake at full operating capacity is 83 acres, when it can contain 460 acre-feet of water (Graaf & Reilly, 1943). The lake can receive inflow from Highline Lateral, Uvalda Street Interceptor, and a ditch (D-2) from the South Plants area. In recent years, the lake has been maintained as a dry basin and has been used for emergency flood control (Ebasco Services, Inc., 1987c).

Lower Derby Lake

Lower Derby Lake is located in south-central Section 1, west of Upper Derby Lake. Lower Derby Lake was an irrigation reservoir at the time RMA was established, but was modified and incorporated into the Process Water System. In 1942, the lake's storage capacity was increased when the Army modified the existing earthen dam by raising the crest three feet, regrading the side slopes, and installing a new drain line, (U.S. Army Chemical Warfare Service, 1945). The lake bottom was originally lined to reduce leakage but has since been dredged. The surface area of the lake at full operating capacity is 106 acres, when it can contain 970 acre-feet of water.

Lower Derby Lake can receive inflow from Upper Derby Lake, Highline Lateral, Uvalda Street Interceptor, and a ditch from the South Plants area. Outflow goes to Lake Ladora, Sand Creek Lateral and can go to the Rod and Gun Club Pond via an overflow ditch.

Lake Ladora

Lake Ladora is located in the southern half of Section 2, west of Lower Derby Lake. Lake Ladora was an irrigation reservoir at the time RMA was established. It was subsequently incorporated into the Process Water System. The surface area of the lake at full operating capacity is 60 acres, when it can contain 400 acre-feet of water (Graaf & Reilly, 1943; U.S. Army Corps of Engineers, 1983d).

Lake Ladora receives inflow from Lower Derby Lake, Havana Pond through Sand Creek Lateral, and seepage from Sand Creek Lateral. Outflow from Ladora Lake flows west around the south side of Lake Mary.

Lake Mary

Lake Mary is located in west-central Section 2, west of Ladora Lake. Lake Mary was completed in 1960, although further modifications continued until 1975 to increase the size and depth of the lake. The surface area of the lake at full operating level is 9 acres, with a capacity of 60 acre-feet of water. This lake was not directly associated with the Process Water System.

Lake Mary can receive surface inflow from Lake Ladora and from local runoff. Outflow from Lake Mary combines with any overflow from Lake Ladora. These flows are directed north to a drainage ditch along the western edge of section 2, which turns west about 1,000 feet after crossing under "C" street. Flow in this ditch is terminated by a small eathern dam that creates an overflow basin (Plate 2.1-1). A breach in the dam may allow some ponded water to continue to flow to the west an indeterminate distance before infiltrating into the ground (Resource Consultants, Inc., 1982; Ebasco Services, Inc., 1987f).

Rod and Gun Club Pond

The Rod and Gun Club Pond is located in the north-central part of Section 12. It is connected to Lower Derby Lake by a shallow ditch that traverses a gap between two low hills. The pond occupies a natural topographic depression and has a total area of 23.1 acres. The pond receives runoff from a small catchment. When water levels are high enough, overflow from Lower Derby Lake can replenish the water in the pond. This occurred during a high water event in 1973 (Ebasco Services, Inc., 1987a). The pond can also receive overflow from the Uvalda Interceptor when the stage in the Uvalda Interceptor is high enough for water to flow through a low area or cut in its bank. This overflow water from the interceptor flows across a field in an undefined channel before reaching the Rod and Gun Club Pond.

2.1.4 Collection Basins

Six basins, used for the retention of process wastes and waste water or storm runoff, have been constructed on RMA. These basins are natural topographic depressions which have been supplemented by berms and other structures. Associated with these basins are small catchment areas from which runoff drains toward the natural depressions.

Basin A

The Basin A Subcatchment has a total area of approximately 240 acres, in Sections 1 and 36. The subcatchment includes the Basin A disposal area and portions of the South Plants industrial complex. The Basin A disposal area was originally a natural depression which was modified by embankments to provide greater storage for liquid process wastes (Chemical Warfare Service, 1945b). In 1956 the contents of Basin A were transferred to Basin F (PMCDIR, 1977). In 1952 the impoundment dike was raised five feet to handle the additional waste which was to be generated by the operation of the GB Plant (Moloney, 1982).

The subcatchment receives runoff which is transported from the northern part of the South Plants industrial complex through the storm water drainage system under December Seventh Avenue (U.S. Army Corps of Engineers, 1984). Most runoff within this subcatchment collects in low areas and causes local ponding in the Basin A area where it then either infiltrates, transpires, evaporates or remains in storage. Infiltration capacities are low (0.06 - 2 in/hr) for the Basin A area (RCI, 1982). A report by MKE concluded that the total average recharge from ponding in the central pool area of Basin A could be estimated at 0.028 cubic feet/second (20.3 acre-ft/yr) (MKE, 1988; as reported in Ebasco, 1989).

Surface water discharge from the subcatchment occurs primarily along the small drainage on the northwest portion of Section 36, referred to as the Basin A ditch. Flow is from Basin A to Basin B and subsequently out to Basins C, D and E (Blackwell, 1973). Runoff is therefore contained within the basins and either evaporates or infiltrates into the soil. Basin A subcatchment runoff does not directly contribute to any of the major surface water drainages at RMA (Resource Consultants, 1982).

Basin B

Basin B is located in the northeast corner of Section 35. The basin covers 1.77 acres and is a modified natural topographic depression. A series of ditches connecting Basin A to Basins B, D, and E were constructed in 1946. A culvert was built under Sand Creek Lateral in the ditch flowing out of Basin B at this time to prevent overflow water from entering the Lateral. The purpose of this ditch system was to provide a controlled pathway for outflow in the event that the Basin A dam failed and also to provide additional confined containment for liquid waste overflows from Basin A (U.S. Army Chemical Warfare Service, 1946). A new Basin A runoff ditch was constructed in 1957 and used until 1964. Drainage through this ditch can enter Basin B from the Southeast. However Basin B was observed to be dry in 1985 and has been noted to contain only a small marsh with limited catchment area since 1986 (CAPS. 1986).

Basin C

Basin C is an unlined basin that was constructed in 1953 in a natural depression in the south-central portion of Section 26. The basin was designed as the primary overflow containment basin for Basin A wastes prior to construction of Basin F. Basin C covers approximately 73 acres and has a maximum storage volume of 640 acre-ft. In 1953, as part of the project for the construction of Basin C, the Army closed the culvert under the Sand Creek Lateral adjacent to the outfall ditch from Basin B and modified this outfall to divert waste fluids overflowing the Basin into Sand Creek Lateral and ultimately into Basin C via a connecting ditch installed at headgate No. 41 (U.S. Army U.S. Army Corps of Engineers, 1953). From late 1953 until the construction of Basin F in 1956, excess waste fluids from Basin A and Basin B flowed via this pathway, first to Basin C, and then to Basins D and E (U.S. Army U.S. Army Corps of Engineers, 1953). When the culvert under the Sand Creek Lateral was opened after 1956 is not known. The basin was observed to be dry in 1986 (CAPS, 1986).

Basin D

Basin D is located in south-central Section 26 south of Basin F and southwest of Basin C and covers approximately 20 acres. Overflow from the basin goes west to Basin E via 2 ditches (ESE, Inc., 1986c).

Basin E

Basin E covers 29.4 acres in the southwest portion of Section 26, southwest of Basin F and west of Basin D. The storage volume and drainage area of the basin are unknown. Flow is received from Basin D. There is no outflow. By 1980, all the fluids in Basin E had evaporated or infiltrated (ESE, Inc., 1986b).

Basin F

The Basin F subcatchment is located just north of the Sand Creek Lateral drainage, west of the First Creek drainage, and within the South Platte drainage area. The topography of the surrounding area is that of gently undulating grassland and with no well defined drainage patterns. Soil infiltration rates are low to moderate in this area (Resource Consultants, Inc., 1982). The basin is a natural topographic depression which was modified to contain liquid wastes generated at RMA. Basin F was lined with a 3/8 inch thick catalytically blown asphalt liner when originally constructed.

Basin F was a primary disposal site for liquid and chemical wastes at RMA from 1956 to 1981. The basin is roughly oval in shape, 2,900 feet wide at the north end, 1,600 feet wide at the south end. The total area is 92.7 acres which could formerly contain a maximum volume of 746 acre-feet.

Basin F was considered to be a capture system (Resource Consultants, Inc., 1982). Surface water contained in the basin has remained in storage, evaporated or transpired; however, recent construction may have altered the former drainage characteristics of this area. Although the nearby Basins C, D, and E have revegetated, Basin F contained wastes until the Interim Response Action was initiated in 1988.

2.2 Previous Surface Water Investigations

The following section presents a description of the existing surface water monitoring networks at RMA and the results of previous monitoring programs.

2.2.1 Existing Water Quantity Monitoring Network

The locations of the existing quantity monitoring stations at RMA are presented in Plate 2.2-1. These stations have been constructed through the course of the previous monitoring programs conducted at RMA. A consistent notation system to identify both the stream discharge monitoring stations and the water quality sampling stations has not been developed. Plate 2.2-1 (and Plate 2.2-2 discussed later) include the existing station identifying systems. A single system will be developed as part of the data management program for the CMP.

An objective of the CMP will be to continue to evaluate these stations and the network with respect to the surface water management program. This section includes a brief description of the monitoring stations, and the results of a preliminary evaluation of each station conducted as part of the development of the technical plan.

During the Task 44 monitoring program, stream stage at the stations has been recorded continuously from spring through fall using Stevens strip chart recorders. These instruments record the height of the water column in stilling wells that are hydraulically connected with the stream through inlet pipes. The stilling wells, associated with these recorders, become inoperable during the winter months due to freezing. This occurs several weeks before the streams freeze, and water in the wells commonly remains frozen during periods of thaw. Consequently, the Stevens recorders are removed during the winter which means that several months of record are missed each year, including periods of significant flow during thaws and spring runoff. Due to these problems, bubbler recording systems will be procured as part of the CMP to allow measurement of flow year-round. The criteria used in the selection of the recording equipment includes system accuracy and durability, appropriateness of the system for flow conditions within the drainages, maintenance requirements, and the ease with which these systems can be installed at RMA. When this alternative system is selected for a monitoring station, it will be installed in parallel with the Stevens recorders at some stations to allow an assessment of the compatibility of data from the two techniques.

Havana Interceptor

The Havana Interceptor gaging station is located near the south boundary of RMA in the southwest corner of Section 11 (Plate 2.2-1). The station consists of a Stevens recorder which is cased in a protective housing and is mounted on top of a vertical stilling well. This structure is suspended over the center of the Havana Interceptor from a bridge, constructed of two parallel segments of telephone pole. The Havana Interceptor itself is a concrete lined trapezoidal channel designed to carry excess surface and storm flows from the airport and commercial properties located south of

RMA to the Havana Pond (see Plate 2.2-1). No additional control structures are in place in the vicinity of the gaging station.

Since the stilling well is located in the center of the channel, the water level of the flow in the channel is disturbed and the station is frequently clogged with debris. The staff gage mounted on the outside of the stilling well is becoming detached. Previous investigators (Resource Consultants, Inc., 1987) also noted several problems resulting from the position of the stilling well in the center of the channel. The float device, used as the water level indicator for the Stevens recorder, requires approximately 0.20 feet of water above the concrete to become suspended and provide accurate flow data.

Placing a stilling well in the center of a concrete lined channel is not a desirable location for the operation of such a gage. Improvements to the Havana Interceptor gaging station would include the conversion of the stilling well system and Stevens recording equipment to a bubbler gage system for stage measurement. This system is capable of recording flow year-round, functions in a concrete lined channel, and does not affect the flow pattern within the channel.

Peoria Interceptor

The Peoria Interceptor gaging station is located near the southern boundary of RMA, in the southwest quarter of Section 11 (Plate 2.2-1). It is situated in an unlined ditch designed to carry surface and storm sewer runoff from the off-post industrial area to Havana Pond. The station is equipped with a Stevens recorder on top of a stilling well, which is connected hydraulically to the active stream channel by a two inch intake pipe. The primary control structure at the station is a flat crested weir which consists of a narrow plank which is positioned perpendicular to flow and is embedded in the banks on either side of the channel.

The control structure was recently observed to be clogged with debris and rocks which have eroded away from a previously installed, bank reinforcement apron. The entire ditch, both up and downstream of the gaging station, is becoming overgrown with vegetation and clogged with trash. Severe erosion is threatening the access road near the culvert which conveys flow within the Peoria Interceptor onto RMA. A staff gage at the station has been partially destroyed.

Previous investigators (Resource Consultants, Inc., 1987) have noted problems with unmonitored leakage around the west side of the control structure. It is uncertain whether this problem has been remedied. Also in the past, high stages on Havana Pond have resulted in submergence of the Peoria gaging station because of water backing up in the Interceptor. This should continue to be a problem as the Havana Pond is expected to continue to contain storm flows as an integral part of the surface water management system at RMA.

Improvements at the Peoria Interceptor gaging station will include the removal of excess vegetation and debris in the channel; the replacement or repair of the staff gage; and the replacement of the stilling well and Stevens recorder system by a Marsh-McBirney doppler system, installed in the culvert pipe, capable of measuring bidirectional flow and recording flow year-round.

Havana Pond

The Havana Pond gaging station is located adjacent to the earthen embankment on the north side of Havana Pond near the center of Section 11 (Plate 2.2-1). The station consists of a Stevens recorder in a protective box which is mounted on a vertical stilling well, together with a staff gage. The stilling well is positioned at the low stage waterline of Havana Pond and is hydraulically connected to the pond.

A spillway will be constructed on the dam, and the pond will continue to be utilized as a flood control structure. A new gage will be constructed in the Sand Creek Lateral downstream of this spillway.

Ladora Weir

The Ladora Weir gaging station is located in the southeast corner of Section 2 (Plate 2.2-1) in a complex of channels connecting Lower Derby Lake, Lake Ladora, and the Sand Creek Lateral. The station is situated to monitor flows out of Lower Derby Lake which can be directed into Lake Ladora or Sand Creek Lateral. Flows originating in the Sand Creek Lateral can be diverted to Lake Ladora and are not presently monitored at the Ladora Weir.

The gaging station consists of a Stevens recorder in a protective case which is fitted onto a wooden deck. This deck, in turn, covers a box structure that receives flow from Upper Derby Lake. A stilling well and staff gage are also located in the box under the deck. The primary control structure at the station is constructed with two, 2-inch-wide planks fitted on top of the concrete wall of the box, which allow the flow to be diverted.

Previous investigators (Resource Consultants, Inc., 1987) have reported leaks in various components of the weir, turbulence in the stilling well, and malfunctioning by the Stevens recorder's float device. Potential improvements which could be implemented at the Ladora Weir station could include the location and sealing of any leaks.

An additional Stevens recorder will be installed on the Sand Creek Lateral to monitor flows to Lake Ladora. An existing flume can be reconstructed and used for this monitoring station.

South Uvalda

The South Uvalda gaging station is located on the Uvalda Interceptor in south central Section 12 (Plate 2.2-1). It is situated in an unlined ditch designed to carry surface and storm sewer runoff from off-post residential and industrial properties to the Derby Lakes. The station is equipped with a Stevens recorder encased in a protective cover. The recorder is located on top of a stilling well which is connected hydraulically to the active stream channel. The primary control structure at the station consists of a V-notch in a 12-inch-wide concrete weir. A staff gage is located in the active channel.

It was recently observed that the ditch and channel were clogged by vegetation and trash. It was further noted that the V-notch in the concrete weir is deteriorating and that the staff gage does not extend high enough and is overtopped even during moderately high flows.

Possible improvements to the South Uvalda station might include the clearing of excess material from the entire length of the Interceptor, the extension of the existing staff gage, and the replacement of the stilling well and Stevens recorder system with an alternative system capable of recording flow year-round.

North Uvalda

The North Uvalda gaging station is located along the Uvalda Interceptor in the southeast corner of Section 1 (Plate 2.2-1). It is positioned on the segment of the Interceptor that delivers runoff to Lower Derby Lake. A diversion structure, located approximately 1,000 feet upstream, can combine the flow in Uvalda Interceptor and the Highline Lateral and divert flows to either Upper Derby or Lower Derby Lake.

The station consists of a Stevens recorder in a protective box which is mounted on a stilling well, and a staff gage. The well is situated adjacent to the active stream channel and is hydraulically connected to the stream with intake pipes. The primary control structure at the station is a broad-crested concrete weir.

No adverse field conditions were apparent during a recent visit to this gaging station. Previous investigators (Resource Consultants, Inc., 1987) have reported this station to be relatively trouble free.

Highline Lateral

The Highline Lateral gaging station is located on the Highline Lateral in the northeast corner of Section 12 (Plate 2.2-1). It is situated along the unlined Highline Lateral irrigation ditch, which is used to deliver Army owned shares of irrigation water to the Derby Lakes. The station consists of a Stevens recorder in a protective box which is mounted on a stilling well, and a staff gage. The stilling well is located on the northeast side of the Highline Lateral and about 5 feet from the main channel. It is hydraulically connected to the main channel by a small feeder channel. This feeder channel is located about 10 feet upstream of a sharp-crested weir which serves as the primary control structure.

No adverse field conditions were apparent during a recent visit to the gaging station. Previous investigators (Resource Consultants, Inc., 1987) noted minor operational difficulties but found the station to be relatively trouble free.

South First Creek

The South First Creek gaging station is currently located on First Creek in south central Section 5 but will be moved upstream to a location in Section 8 (Plate 2.2-1). The station consists of a Stevens recorder in a protective box which is mounted on a stilling well, and a staff gage. The primary control structure at the station is a broad crested concrete weir approximately 24 inches wide.

No adverse field conditions were apparent at this station during a recent visit. Previous investigators (Resource Consultants, Inc., 1987) report the station as relatively trouble free except that during high flows First Creek has tended to back up and overflow its banks behind some undersized culverts located immediately upstream of the station. RMA is currently upgrading the culverts and raising the road level in order to prevent overtopping. The area south of the road will act as a detention pond. The gaging station will be moved upstream of these structures. The new gage location will include a concrete control structure and a bubbler system which is capable of monitoring stream stage year-round.

North First Creek

A gaging station was formerly located on First Creek near the north boundary of RMA in north central Section 24 (Plate 2.2-1). This station was destroyed during construction activity which included widening and flattening the channel and adding large culverts at two locations where service roads cross First Creek. The North First Creek gaging station will be replaced with a new station. The new station will be at a location that will not receive flows from the Sewage Treatment Plant, located near the center of Section 24, which had been monitored at the original North First Creek gaging station location. The new station will be equipped with a concrete control structure, a staff gage, and a bubbler system capable of recording stream stages year-round. An additional improvement to the site would be to enlarge the culvert which passes First Creek water beneath 96th Avenue in order to prevent high flows from backing up on RMA property.

South Plants Ditch

The South Plants Ditch gaging station is located near the center of Section 1 (Plate 2.1-1) at a diversion structure that channels flow from the South Plants area to either the east or west end of Lower Derby Lake. The station consists of a Stevens recorder in a protective box, which is mounted on a stilling well, and a staff gage. The primary control structures at the station are sharp-crested, V-notch weirs. These are mounted on wooden planks attached to the outflow sides of the diversion structure. Flow could pass over both weirs at the same time. The weir on the southeast is approximately 1/2 foot lower in elevation.

No adverse field conditions were apparent during a recent visit to this gaging station. Previous investigators (Resource Consultants, Inc., 1987) have reported seepage around the weir planks, and no measurable flow during their entire 18 months of record keeping.

Basin A

The Basin A gaging station is located in a drainage ditch in the southwest corner of Section 36 (Plate 2.2-1), where storm sewer and ground water (which may be infiltrating from the South Plants area) is delivered into Basin A. The station consists of a Stevens recorder in a protective box which is mounted on a stilling well, and a staff gage. The primary control structure at the station is a sharp-crested weir. Previous investigators (Resource Consultants, Inc., 1987) reported this station was relatively trouble free.

North First Creek Off Post

The North First Creek Off-Post gaging station is located north of RMA, upstream of Highway 2. The station consists of a Stevens recorder in a protective box which is mounted on a stilling well, and a staff gage. The control structure at the station is an H-flume. Previous investigators (Resource Consultants, Inc., 1987) reported that the station was relatively trouble free but that the flume may not be set low enough in the channel to prevent high flows from overtopping the banks and circumventing the station.

This flume will be reworked so that the gage will be only used to measure low flows for the purpose of evaluating the changes in low flow between this location and the North First Creek gage. Flows exceeding the capacity of the flume (19.2 cfs) will not be gaged or reported. Low flow measurements will be reported to the Commerce City Department of Public Works.

Lake Monitoring Stations

Lower Lakes

Staff gages have been installed at observation points on each of the Lower Lakes for the purpose of water level monitoring. The locations of these observation points are shown in Plate 2.2-1.

The Upper Derby Lake staff gage is divided into increments of 0.1 foot, and has a range of 0 to 10.0 feet. The lake will overtop its dam at a staff gage reading of approximately 9.0 feet; however, water from Upper Derby Lake will normally flow through a culvert to Lower Derby Lake or to Eastern Upper Derby Lake. The elevation of the zero reference point of the staff gage at Upper Derby Lake is unknown and needs to be surveyed.

The Lower Derby Lake staff gage is also divided into increments of 0.1 foot, and has a range of 3.0-21.0 feet. This lake will overtop its dam at a gage reading of 21.2 feet; however, water from Lower Derby Lake is typically channeled to the Rod and Gun Club Pond, Lake Ladora, and Sand Creek Lateral. The zero reference elevation is 5231.2 feet above sea level.

The Ladora Lake staff gage has a precision of 0.1 foot. It spans a vertical distance from 0 to 13.0 feet and overtopping would occur at 12.4 feet. The zero reference elevation of the Ladora Lake staff gage is 5207.3 feet above sea level.

Water elevation at Lake Mary is monitored by a staff gage with a precision of 0.1 foot that ranges from 0 to 2.00 feet. Overflow occurs at 1.34 feet. The zero reference elevation is 5202.63 feet above sea level.

Previous investigators (Resource Consultants, Inc., 1987) report that each of these staff gages are in good condition and that no problems have arisen when water level observations have been made. The installation of continuously recording monitoring equipment to supplement the existing staff gages would provide increased precision in water level data from the Lower Lakes.

Lake Ladora Pump Station and Sewage Treatment Plant Effluent Meters

Totalizing flow meters have been installed at the sewage treatment plant in Section 24 and at the pumphouse on the west end of Lake Ladora. Both meters measure flow in hundreds of gallons.

The sewage treatment plant processes on-post sanitary sewer effluents and discharges treated water to a marshy ditch which flows to First Creek. The Lake Ladora meter measures the volume of water pumped from the lake that is used for steam generation. It does not necessarily measure all water leaving Ladora Lake through pump losses, pipe losses, seepage, and bank overflow. Furthermore, it is thought that this flow meter has not been in continuous operation during recent years.

2.2.2 Surface Water Flow Characteristics

Although surface water flow on RMA has been monitored for several years, little verified information is available on basic streamflow characteristics (e.g. average daily flows) or discharge - frequency relationships. One step in the implementation of the CMP is to compile, in coordination with the Office of the Program Manager and the RI/FS Contractor, all available data that have been generated during the previous monitoring programs. These basic data (e.g. field discharge measurements, Stevens recorder charts, station rating curves) must be verified prior to the evaluation of flow information collected during the CMP.

2.2.3 Existing Water Quality Network

The locations of the existing water quality monitoring stations at RMA are presented on Plate 2.2-2. Previous reports (e.g. ESE, Inc., 1986a) indicate that water quality samples have been collected by ESE at 37 locations on RMA. The procedures which have been employed in the collection of samples are described in the Task 44, Water Monitoring Program, Technical Plan (ESE, Inc., 1987a).

An objective of the CMP is to continue to evaluate this monitoring network, as well as the sampling and analytical procedures that have been used in previous monitoring programs. A specific concern to be addressed will be whether the existing network can adequately monitor those flows which will result from the implementation of the surface water management program at RMA. The ability to monitor such flows will be critical in evaluating the effect of the management program on contaminant migration by surface water pathways.

2.2.4 Surface Water Quality and Contaminant Transport

The surface water features, described in Section 2.1, drain several potential point and non-point sources of contamination. Contamination of the surface water on RMA may be derived from runoff out of contaminated areas on RMA (e.g. the South Plants Manufacturing Complex) or from offsite sources, and from the discharge of contaminated ground water into streams (n.b. First Creek). Contaminants may be transported in a dissolved state, or adsorbed onto sediment particles which are transported by the runoff. Both of these mechanisms may be significant in transporting contaminants between different areas of RMA and offpost.

The following section briefly describes the relationship between the surface water quality monitored at RMA and the potential contaminant sources. The results of this preliminary evaluation confirm the need to compile and verify all of the available water quality data which has been collected on RMA (see Section 2.2.2). Such a program must be completed before an adequate assessment of surface water quality can be conducted. This, in turn, would facilitate the refinement of the existing monitoring network.

First Creek Drainage

ESE (1987b) reports that diisopropyl methyl phosphonate (DIMP), dibromochloropropane (DBCP), and organochlorine pesticides have been detected in water samples collected from First Creek (Sample locations 08-001, 08-002, 31-001, and 24-002). Potential sources for these contaminants may include the South Plants Manufacturing complex, other contaminated areas and offpost sources, or ground water discharge into First Creek.

Spaine and Gregg (1983) monitored storm water runoff from the South Plants area discharging to the First Creek drainage basin. Samples were collected from the ditch that empties into Upper

Derby Lake, northeast of sampling location SW01002 (Plate 2.2-2). This location corresponds to Spaine and Gregg sample site number 1 and Shell Chemical Company sample site number 3. Samples collected by Shell from three storm events in 1979 and 1980 contained the following compounds at concentrations above the method detection limits; carbon tetrachloride, tetrachloroethylene, trimethyl phosphate (TMPO), chloroform, dimethylmethyl phosphate (DMMP), and dieldrin (See Table 2.2-1). All other target analytes were below the method detection limits.

Surface water runoff is directed from the south-central portions of the North Plants facility to First Creek via a east-northeast oriented ditch (Plate 2.2-2). Previous samples collected from First Creek near the junction with this ditch at sampling location SW30002 had no detectable concentrations of target analytes (ESE, 1986a). No previous sampling data exist for sample location SW30001.

The potential discharge of contaminated ground water into First Creek may also influence surface water quality, particularly during periods characterized by base-flow conditions. No verified information is available, however, to enable a detailed evaluation of the volume or quality of ground water that may discharge into First Creek from the South Plants area. A water budget analysis of First Creek was conducted between the upstream and downstream boundaries of RMA (USAWES, 1984). The results of this investigation showed that a net average of 0.21 cubic feet per second (cfs) seeped from the stream to the ground water between these two points from May through December. No information was available from this study on variations in this seepage rate over the length of the creek, or of the implications of the relationship between surface water and ground water to water quality.

Contaminants in First Creek may also be derived from other point and non-point sources on RMA. Sections 5, 6, 19, 20, 29, 30, 31 and 32, which lie within the First Creek Drainage on RMA, are reported to contain the following categories of potential source areas: munition impact areas, burn sites, disposal pits, spill areas and trenches. Potential contaminants from the source areas, including volatile organic constituents, pesticides, herbicides and heavy metals, could be transported by runoff into First Creek.

It is notable that organochlorine pesticides have been detected at the upstream boundary of RMA, not only on First Creek but also on the Havana and Uvalda Interceptors. These data suggest that land use practices upgradient of RMA may be a source of the contaminants detected in the drainages. It is probable that the nature and concentrations of such contaminants will vary depending on flow conditions and land use within each of the drainages. For example, under base

Table 2.2-1

Storm Water Runoff from South Plants to First Creek (units in ppb)

	11/23/79	4/1/80	4/24/80
Dieldrin	1.0	0.9	ND
Dimethylmethylphosphonate	ND	3	4
TMPO	7	2	4
Chloroform	ND	ND	5
Carbon Tetrachloride	16	166	29
Tetrachloroethylene	ND	12	5

ND: not detected at method detection limit

Source: Spaine & Gregg, 1983

flow conditions, supplemented by water derived from the watering of lawns in residential area, pesticides and herbicides may be detected. In contrast, hydrocarbon contaminants derived from spills in industrial areas may be detected in storm runoff.

Verifiable data from previous monitoring programs have not been compiled to enable an assessment of the significance of offpost sources to water quality on RMA. Furthermore, it is likely that the contaminants derived from offpost sources, will not have been adequately characterized in the analysis of the RMA target compounds. More comprehensive analytical techniques (including GC/MS analysis) will be needed to more fully characterize such contaminants.

Other Drainage Basins

A preliminary review, conducted during the development of this work plan, has indicated that extensive monitoring of water quality has not been conducted in the remaining drainage basins on RMA. Within the Irondale Gulch drainage, monitoring has primarily been limited to the lakes and diversion channels on RMA. Notably in the drainage basins without a distinct stream channel, runoff and sediment quality have not been monitored, although these could be potential pathways for the migration of contaminated soils.

Diversion Channels

Water quality data collected from the upstream stations on the Peoria and Uvalda Interceptors indicate that contaminants, including pesticides, are migrating onto RMA (ESE, 1986a). Other data indicate that the South Plants Manufacturing Complex is another source of contamination, notably to the Sand Creek Lateral. Spaine and Gregg (1983) report that contaminants may migrate to the Sand Creek Lateral from the South Plants area through the surface water drainage system.

RMA Lakes

As a result of accidental spills in the South Plants area and losses into the Process Water System in the past, the bottom sediments and, to a lesser extent, the water in the Derby Lakes and Lake Ladora were contaminated by various compounds. This contamination occurred at least as early as the late 1950's and continued into the 1960's. Water samples collected from these lakes have been found to contain methylene chloride, benzene and dieldrin.

Spaine and Gregg (1983) monitored the quality of storm-water runoff from the South Plants area into the Derby-Ladora Lake complex in 1980. The following compounds were detected in samples of the runoff: azodrin, bladex, atrazine, p-chlorophenylmethylsulfone, dieldrin, DMMP, TMPO and DBCP. All of the other target analytes were below the method detection limits.

USAWES (1983) reported that water samples collected from Lake Mary contained dieldrin and methylene chloride. The pathway by which these contaminants reached the lake is uncertain.

The results of the surface water quality monitoring programs on the RMA lakes have identified the South Plant complex as a primary source of contaminants. Considerable uncertainties remain, however, as to the role of the lakes as a source of contaminants to the ground water or other surface water features.

Collection Basins

The Basin A subcatchment collects runoff from several contaminant sources. These include the South Plants industrial complex, several landfills and disposal pits, land contaminated with surface spills and the Basin A disposal basin. There have been many water samples collected and analyzed from the Basin A inflow and standing water. Contaminants include, but are not limited to chloroform, trichloroethene, tetrachloroethane, toluene, xylene, ketones and benzene (Spaine and Gregg, 1983; ESE, 1986a). Varying degrees of surface water contamination would be expected to occur where the surface water comes in contact with any area which had been previously inundated by contaminated wastes. However, offsite migration of contaminants would not be expected since flow does not leave RMA but is transferred from the subcatchment to downgradient basins.

A water sample from the channel carrying water from Basin C and Basin D contained p-chlorophenylmethyl sulfoxide (PCPMSO) and dibutyl phthalate; water collected in Basin E which receives overflow from Basins C and D and runoff from Section 35, contained DIMP, PCPMSO and dibutyl phthalate. However, only six compounds were analyzed for this investigation (Grabbe, 1976). Basin F, a disposal pond equiped with a catalytically blown asphalt liner, received effluent from an variety of sources. It is currently being remediated and has been isolated from the surface water system in the area.

2.3 Surface Water Management Program

As an integral element to an agreement with the City of Denver to manage surface water flows onto RMA, the Office of the Program Manager is developing a comprehensive surface water management program. The key objectives of this program are to ensure that the management of storm and nuisance flows which enter RMA is integrated with on-going clean-up efforts and that liabilities associated with the offpost migration of the surface water (e.g. the potential offsite transport of contaminants by storm runoff) are minimized.

The management program is currently being developed by the Office of the Program Manager. The scope of the program will be dependant on the results of discussions with the City and congressional representatives, as well as the results of technical studies which are underway (e.g. Urban Drainage and Flood Control District studies on the First Creek and Irondale Gulch drainages). As an interim step in the development of the program, however, the Office of the Program Manager is implementing three significant changes in the manner in which surface waters have been managed on RMA.

An initial step in the development of the program is that the uncoordinated movement of surface water on RMA will be eliminated. Under the Surface Water Management Program, the office of the Program Manager will coordinate with the Chief Facility Engineer at RMA in order that the movement of surface water required to meet water needs for facilities at the Arsenal and RI/FS and CMP activities will not be in conflict. Secondly, storm flows within the Uvalda Interceptor may be routed to Upper Derby Lake with any overflow possibly being passed to First Creek. Certain storm flows which enter Havana Pond will be routed through the Sand Creek Lateral to either Lake Ladora or to the Irondale Gulch basin where the flows will be dissipated and allowed to infiltrate.

As these elements of the surface water management program are implemented, an objective of the CMP will be to monitor the adequacy of the program and provide for its refinement. Furthermore, the increased understanding of the surface water system on RMA which will result from the operation of the CMP, will facilitate the development of a more comprehensive management program.

3.0 TECHNICAL PROGRAM

In order to meet the objectives described in Section 1.0 of this Technical Plan, the surface water program has been divided into sub-elements which are described in the following sections.

3.1 Evaluation of Existing Surface Water Monitoring Programs

The following sections describe the evaluation of existing surface water monitoring data and equipment repair and procurement. Both of these activities are required for the successful implementation of the surface water element of the CMP.

3.1.1 Assessment of Historical Surface Water Flow and Quality Data

Surface water flow and quality data have been collected at RMA for a number of years as described in Section 2.0. Previously collected data will be integrated with data collected from the CMP to form a defensible data base to optimize the utility of long term monitoring data. A long term data base enhances the interpretation of surface water flow and quality data to better understand the surface water flow regime which, in turn, enhances the ability to identify and quantify changes in the pattern of contaminant distribution and to support remedial action. However, before the long term data base can be formed, the past data must be evaluated to verify that methodologies used are consistent with present methods in order for the data to be comparable. In addition, quality assurance requirements under which the past data were collected will be evaluated to verify how the past data can be utilized. The assessment of existing surface water flow and quality data will be completed at the end of the first year of the CMP. The verified past data and the first year of data from the CMP will be used to assess the need for modifying the existing monitoring program.

3.1.2 Repair and Procurement of Equipment

An inventory of surface water monitoring equipment owned by the Army and utilized by ESE, Inc. under Task 44 is provided in Table 3.1-1. The equipment will be examined by the R.L. Stollar & Associates, Inc. (Stollar) Surface Water Team.

Following this inspection, any necessary repairs together with the procurement of replacement or spare parts and additional equipment, will be completed. These activities are necessary to bring the system to an operational status and to implement the CMP.

Table 3.1-1

Task 44 Monitoring Equipment

Equipment List

8	Steven's Type F Water Level recorders, Model 68 with Quartz Multispeed Timers.
4	Steven's Type F Water Level recorders, Model 68 with Auto-rewind, Spring-driven Timers.
1	Marsh-McBirney Model 250 Current meter.

A partial summary of Stollar activities to inspect Army owned equipment, procure additional equipment and spare parts, and upgrade the surface water monitoring network is as follows:

- Verify ESE, Inc. inventory; inspect existing equipment and perform field inspections to assess preparation requirements.
- Order additional required equipment and spare parts.
- Receive, inspect and prepare new equipment for installation.
- Install Stevens recorders and new equipment at sites.
- Calibrate equipment and perform pre-monitoring maintenance of equipment.
- Prepare all monitoring and sampling logs, containers for first quarter sampling; organize field equipment.

3.2 Surface Water Quantity

The following sections describe the surface water quantity monitoring sub-element which is to be conducted at RMA. Detailed field procedures will be presented in the Field Procedures Manual and will meet USATHAMA QA requirements.

3.2.1 Surface Water Monitoring Strategy

CMP surface water monitoring is composed of four components, continuous surface water quantity monitoring, high surface water flow (storm) event monitoring, monitoring of the implementation of the surface water management plan and remedial action monitoring.

Surface water quantity will be evaluated seasonally through continuous recording of stage and monthly discharge monitoring. Discharge data will also be collected during two high flow periods (following summer or fall storm events or in response to high spring runoff plus high rainfall) in order to enable assessment of the impact of high surface water flow events on the RMA hydrologic system and to determine total flows at each monitoring station. The criteria to identify a high flow event will be established on the basis of the stream flow and precipitation data which are currently being compiled by the PMO.

3.2.2 Location of Surface Water Monitoring Stations

During the first year of the CMP, the existing monitoring network will be maintained (see Plate 2.2-1) with only limited additions or modifications. A review of the existing network (see Section 2.2) indicates that it does address the major surface water features on RMA. Potential shortcomings which have been identified in the network (e.g. absence of monitoring stations in those basins with less well defined drainages) and changes which are necessitated by the implementation of the surface water management program, will be addressed during the initial phase of the CMP.

The interim measures which are being implemented by the Office of the Program Manager as part of the management program (Section 2.4) may cause significant changes to the surface flow regime at RMA. In order to monitor these changes, a number of specific modifications are proposed to the monitoring network as part of this Technical Plan.

The gaging stations at North and South First Creek have been disrupted by construction activities on RMA. Both stations will be relocated upstream of the new structures.

The management program will also result in increased usage of the Sand Creek Lateral and the ditch that drains excess storage from Ladora Lake into an undefined basin on the east side of Section 3. It is the recommendation of the Stollar team that two new monitoring stations be installed to monitor these flows. Flows in the Sand Creek Lateral could be monitored from an existing Parshall flume located in the Lateral channel, just west of the Ladora Weir gaging station. This flume is currently in a state of disrepair and should be renovated prior to the operation of the station. The sections of Sand Creek Lateral to be subjected to more frequent use would also require clearing of excess vegetation and debris.

Overflow from Lake Ladora passes through a ditch along the south side of Lake Mary, into a poorly defined channel adjacent to C Street in Section 2, and finally through a small culvert into an undefined basin in Section 3. A gaging station should be constructed as part of an outlet structure for Lake Ladora or as part of an erosion control structure in the overflow ditch.

3.2.3 Surface Water Data Acquisition

Surface water monitoring to continue the determination of surface water quantity includes monitoring both lakes/ponds and streams. Meteorological data, such as precipitation and evapotranspiration, needed to fully interpret the surface water data will be provided in conjunction with the meteorological monitoring program. The meteorological monitoring program is described in the Air Quality Monitoring Technical Plan.

Streamflow data that will be monitored are stage and discharge. Physical data will be collected through direct measurements of staff gages and/or continuous water level recorders for stage and through the use of flow meters, weirs, or flumes for discharge. Stream stages will be recorded weekly with the staff gages, and continuous monitoring stations will also be visited weekly. Discharge measurements will be made on a monthly basis for the seasonal surface water quantity monitoring, with additional measurements made of two high surface water flow events. Stage-discharge relationships will be established to enable determination of discharge at all stages recorded by the continuous water-level recorders.

The monitoring activities to be conducted at each station are summarized in Table 3.2-1. The Stevens recorders will be serviced on a weekly basis. This will include collecting and replacing strip charts, checking recorder operation, calibrating strip charts to the observed stage and initial time, and removing obstructions from stilling wells and channel sections. Instantaneous discharge measurements will be made whenever unusual flow conditions are observed in addition to the scheduled monthly measurements.

The stage of a stream or lake/pond is the height of the water surface above an established datum plane. The water surface elevation referred to an arbitrary gage datum is called gage height. Gage height data are used with a stage-discharge relation in computing records of stream discharge. The reliability of the discharge record is therefore dependent on the reliability of the gage height record, as well as on the accuracy of the stage-discharge relation.

Discharge is defined as the volume rate of flow of water. Discharge measurements are made at monitoring sites at various stages to determine the discharge rating for the site. Once the rating is established additional measurements are made to confirm the stage discharge relationship and to confirm that stream channel conditions have not changed causing an alteration to the rating. Discharge measurements will be made using standard USGS monitoring techniques. Low flow measurements will be made using a Price Pygmy current meter and top setting wading rod. Higher flows will be measured using a Standard Price current meter and top setting wading rod. All measurements will be wading measurements where the hydrographer will wade into the stream to collect the flow observations. When major flow events occur that can not be measured by wading techniques a slope area type of indirect measurement will be made if the flow event would require an extension of the stage discharge relationship (rating curve) more than 20 percent above the

Table 3.2.1

Stream Discharge and Lake Monitoring Activity Summary

		ACTIVITY		
STATION	TYPE	WEEKLY	MONTHLY	STORM EVENT
1. Havana Interceptor	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
2. Peoria Interceptor	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
3. Havana Pond	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
4. Ladora Weir	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
5. South Uvalda	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
6. North Uvalda	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
7. Highline Lateral	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
8. South First Creek	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
9. North First Creek	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
10. South Plants Ditch	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage

Table 3.2.1 (continued)

		ACTIVITY		
STATION	TYPE	WEEKLY	MONTHLY	STORM EVENT
11. Basin A	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
12. First Creek Offpost	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
13. Upper Derby Lake	Staff Gage	Monitor Gage	Monitor Gage	Monitor Gage
14. Lower Derby Lake	Staff Gage	Monitor Gage	Monitor Gage	Monitor Gage
15. Ladora Lake & Pump Meter	Staff Gage Flow Meter	Monitor Gage Monitor Meter	Monitor Gage Monitor Meter	Monitor Gage Monitor Meter
16. Lake Mary	Staff Gage	Monitor Gage	Monitor Gage	Monitor Gage
17. Sewage Treatment Plant Effluent Meter	Flow Meter	Monitor Meter	Monitor Meter	Monitor Meter
18. Sand Creek Lateral (proposed)	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage
19. Lake Mary Ditch (proposed)	Recording Station	Service Recorder	Discharge Measurement/ Monitor Crest Gage	Discharge Measurement/ Monitor Crest Gage

highest measurement. Indirect measurements are made after the flow event has occurred and includes surveying highwater marks, stream channel cross-sections and stream slopes.

Continuous records of discharge at surface water monitoring sites are computed by applying the discharge rating for the stream to records of stage. Discharge ratings for the monitoring sites will be developed by plotting the stage and discharge from the discharge measurements made during the CMP and previous studies on log-log paper and fitting the best fit line, called the rating curve, between the plottings. It is very important to the quality of the rating curve that discharge measurements for the higher flow events are included and at this point in time the only source for these higher measurements is from previous studies conducted at RMA. Once the rating curve has been developed the discharge for a recorded stage can be determined. Because of the importance of stage-discharge relations, the assessment of past data is essential for comparability with surface water data collected as part of CMP.

Measurements of instantaneous discharge and stage will be obtained during two high flow events at each station. Crest stage gages will be installed at the stream monitoring stations to allow the measurement of peak stages during high flow events.

Warning of major rainfall-runoff events will be received from a meteorological contractor who will forecast storm-events on a daily basis for the Stollar team and identify the location of storm activity. High flows associated with snowmelt will be anticipated on the basis of snowcover, temperature and precipitation conditions.

Physical data on the lakes and ponds will be collected by direct measurements of staff gages and evaluating changes in the area of the lake/pond over time in order to confirm previously established stage relationships. Staff gages will be monitored weekly and for the two high surface water events. The area of the lake/pond will be obtained from previous surveys of lake/pond area. Lake/pond storage will be calculated on a monthly basis and for the two high surface water flow events using the refined stage relationship.

3.2.4 Surface Water Monitoring Station Maintenance

Prior to the initiation of the CMP, the Stevens recorders which have been used during the Task 44 monitoring program, will be re-installed in the stilling wells at the monitoring stations. In addition, the general maintenance activities (e.g. repair or installation of gages and control structures, clearing of vegetation) which were identified for each station in Section 2.2 of this plan will be completed.

The assessment of the monitoring stations conducted during the development of this work plan (see Section 2.2) has indicated that the stilling well systems used at the stations have severe limitations due to freezing. During the first year of the CMP, alternative recording systems, bubbler systems, will be procured to augment the surface water monitoring network. The new systems and the stilling wells with Stevens recorders will be run in parallel at some stations during one summer to enable an assessment of the comparability of the data from these two systems and to allow time to correct any problems with the new systems. The acquisition and installation of alternate recording systems will not be recommended unless the quality of the stage data to be collected will be improved.

3.3 Water Quality

Justification for selecting sample locations, the strategy for the frequency of sampling and the analytical methods to be used are presented in this section. Specific sample handling procedures are discussed in a separate document, entitled Field Procedures Manual for the Comprehensive Monitoring Program, Rocky Mountain Arsenal. All water quality sampling and analytical procedures will be in accordance with PM RMA/USATHAMA requirements, for sample collection, sample preservation, sample shipment, sample analysis, and Chain-of-Custody.

3.3.1 Surface Water Quality Monitoring Network

Under the CMP, samples will initially be collected from the network utilized in Task 44. These locations are illustrated in Plate 2.2-2. As the results of the Task 44 program are being interpreted as the CMP is implemented, it is prudent to maintain the established network so that a consistent water-quality baseline can be verified. A basis for including additional sampling locations, such as along First Creek, will develop as water-quantity investigations identify specific areas of concern, such as where surface water and ground water appear to be in communication. As new and historic water quality data become available for interpretation, (see Section 3.1), the sampling network may be modified.

3.3.2 Surface Water Quality Monitoring Strategies

Surface water quality samples will be analyzed for the parameters listed in Table 3.3-1. For the first year of the Surface Water CMP, all water samples will be analyzed for the entire suite of parameters to maintain continuity in the water quality monitoring program. After the first year of sampling, the parameter list will be evaluated. Except for isolated areas (South Plant and Basin

A ditch areas), available surface water quality data suggest that contamination of surface water is not severe and is limited to a few classes of compounds. Therefore, the analytical suite may be reduced to eliminate the collection of data that do not materially add to the assessment of contamination related to RMA. Other severely contaminated areas may be found during the first year of monitoring or remedial activities may require a modification of the analytical suite. After the first year of monitoring, the analytical suite will become more focused for site specific areas.

Data collected during previous surface water monitoring programs (see Section 2.2.4, page 24) have indicated that organic contaminants may be derived from off-post sources. These contaminants may then move onto and across RMA through the surface water pathways. The suite of target analytes listed in Table 3.3-1 may not be sufficiently comprehensive to include such contaminants. Consequently, the analysis of the target analytes will be supplemented by GC/MS analysis of selected samples. The sampling and analytical procedures to be employed in this program are discussed more fully below.

Table 3.3-2 summarizes the frequency at which water quality samples will be collected during the CMP. At 10 sites, listed in Table 3.3-2 and located on Plate 2.2-2, samples will be collected during the spring and fall, in order to characterize seasonal trends in water quality. In addition, samples will be collected at these stations during two high flow (storm) events. All of the sampling activities will be conducted in conjunction with discharge measurements. The manual collection of samples during high flow events will be complemented at selected sites by the use of automated sampling equipment that will be triggered during a rising stream stage. This sampling equipment collects time integrated samples from a single intake point in the stream cross-section during turbulent flow conditions.

Four samples will be collected on an annual basis from the lakes during the spring (Table 3.3-2). In addition, samples from the Highline Lateral, South Plants Steam effluent, and Sewage Treatment effluent will be collected annually during the spring. Fifteen additional samples will also be collected annually. These samples will be collected during storm events from those stations where the ephemeral nature of flow does not allow for seasonal monitoring, or to meet specific sampling objectives which have been identified during the CMP (e.g. a point source of contamination, sampling of the Highline Lateral where flow begins). Table 3.2-3 lists the potential locations where the additonal 15 annual samples may be collected.

Table 3.3-1
Analytical Methods for Surface-water Quality and Sediment Samples

Analyte Suite	Parameters	USATHAMA Certified Method Number for Water	USATHAMA Certified Method Number for Soil
Volatile Aromatics		AV8	AA9
	Benzene		
	Toluene		
	Chlorobenzene		*
	Ethyl benzene		
	1,3-Xylene		
	1-2-Xylene		
Volatile Halocarbons		N8	NN9
	1,1-Dichloroethene		
	1,1-Dichloroethane		
	1,2-Dichloroethene		
	Chloroform		
	1,2-Dichloroethane		
	1,1,1-Trichloroethane		
	Carbon Tetrachloride		
	1,1,2-Trichloroethane		
	Tetrachloroethane		
	Chlorobenzene		
	Methylene Chloride		
DBCP		AY8	S9
	1,2-Dibromo-3-chloropropane		
Organosulfur Compounds		AAA8	HH9
	Dimethlydisulfide		
	1,4-Oxathiane		
	1,4-Dithiane		
	Benzothiazole		
	P-Chlorophenylmethyl sulfide		
	P-Chlorophenylmethyl sulfoxide		
	P-Chlorophenylmethyl sulfone		
Organosulfur Pesticide		KK8	KK9A
	Hexachlorocyclopentadiene		
	Aldrin		
	Isodrin		
	p,p'-DDE		
	Dieldrin		
	Endrin		
	p,p'-DDT		
	Chlorodane		

Table 3.3-1 (cont'd.)

Analyte Suite	Parameters	USATHAMA Certified Method Number for Water	USATHAMA Certified Method Number for Soil
Hydrocarbons	P8	PP9	
	Bicycloheptadiene		
	Dicyclopentadiene		
	Methylisobutyl ketone		
Anions		HH8A	HHH9
	Bromide	*	
	Chloride		
	Fluoride		
	Sulfate		
Nitrate		LL8	*
	Nitrate		
Arsenic		AX8	B9
	Arsenic		
Mercury		CC8	Y9
	Mercury		
ICP Metals		GG8	P9
	Cadmium		
	Chromium		
	Copper		
	Lead		
	Zinc		
	Magnesium		*
	Calcium		*
	Sodium		*
	Potassium		*
Volatiles		J8	DCN9
	1,1,1-Trichloroethane		
	1,1,2-Trichloroethane		
	1,1-Dichloroethane		
	1,1-Dichloroethene		*
	1,2-Dichloroethane		
	1,2-Dichloroethene		
	Benzene		
	Bicycloheptadiene		*
	Carbon tetrachloride		
	Chlorobenzene		
	Chloroform		
	Dimethyldisulfide		*
	Dicyclopentadiene		*

Table 3.3-1 (cont'd.)

Analyte Suite	Parameters	USATHAMA Certified Method Number for Water	USATHAMA Certified Method Number for Soil
Volatiles (cont'd.)			
	Dibromochloropropane		*
	Ethylbenzene		
	Methylene Chloride		
	Tetrachloroethene		
	Toluene		
	Trichloroethene		
	1,3-Dimethylbenzene		
	Xylene		
	Methylisobutylketone		
Semi-volatiles		JJ8	L9
	Aldrin		
	Atrazine		
	Hexachlorocyclopentadiene		
	Chlordane		
	Chlorophenylmethyl sulfide		
	Chlorophenylmethyl sulfoxide		
	Chlorophenylmethyl sulfone		
	Dibromochloropropane		
	Dicyclopentadiene		
	Vapona		
	Diisopropylmethyl phosponate		
	Dithiane		
	Dieldrin		
	Dimethylmethyl phosphonate		*
	Endrin		
	Isodrin		
	Malathion		
	Oxathiane		
	PPDDE		
	PDDT		
	Parathion		
Cyanide		TF20	
	Cyanide		*
Nitrogen/Phosphate		UH11	
	Atrazine		*
	Parathion		*
	Malathion		*
	Supona		*
	Vapona		*

* not analyzed.

Table 3.3-2
Surface Water Quality Sampling Frequency

Station	Frequency	Parameters	Number of Samples	
			Target	GC/MS
SW11-002 Havana Interceptor	Spring & Fall 2 storm events	Target & GC/MS	4	4
SW11-001 Peoria Interceptor	Spring & Fall 2 storm events	Target & GC/MS	4	4
SW12-005 S. Uvalda Interceptor	Spring & Fall 2 storm events	Target & GC/MS	4	4
SW01-001 N. Uvalda Interceptor	Spring & Fall 2 storm events	Target & GC/MS	4	4
SW08-003 S. First Creek (Replaces 05-001)	Spring & Fall 2 storm events	Target & GC/MS	4	4
SW24-002 N. First Creek	Spring & Fall 2 storm events	Target & GC/MS	4	4
			24	24
SW01-003 South Plants Ditch	Spring & Fall 2 storm events	Target & 10% GC/MS	4	-
SW36-001 Basin A	Spring & Fall 2 storm events	Target & 10% GC/MS	4	-
SW37-001 First Creek Offpost	Spring & Fall 2 storm events	Target & 10% GC/MS	4	-
SW02-002 Sand Creek Lateral	Spring & Fall 2 storm events	Target & 10% GC/MS	4	-
			16	2
SW07-003 Highline Lateral (Replaces SW08002)	Annual (Spring)	Target & 10% GC/MS	1	-
SW01-004 Upper Derby Lake	Annual (Spring)	Target & 10% GC/MS	1	-
SW01-005 Lower Derby Lake	Annual (Spring)	Target & 10% GC/MS	1	-
SW02-001 Ladora Weir	Annual (Spring)	Target & 10% GC/MS	1	-
SW02-003 Ladora Lake	Annual (Spring)	Target & 10% GC/MS	1	-

Table 3.3-2 (cont'd.)

Station	Frequency	Parameters	Number of Samples	
			Target	GC/MS
SW02-004 Lake Mary	Annual (Spring)	Target & 10% GC/MS	1	-
SW02-006 South Plants Steam Effluent	Annual (Spring)	Target & 10% GC/MS	1	-
SW24-001 Sewage Treatment Effluent	Annual (Spring)	Target & 10% GC/MS	1	-
			8	1
15 Additional Samples	Annual (Storm Event)	Target & 10% GC/MS	15	2
Totals			63	29

Table 3.3-3
Potential Locations for Additional Annual Event and Storm Event Sampling

Station Number	Location Name
SW-01002	South Plants Water Tower Pond
SW-02005	Sand Creek Lateral West
SW-04001	Motor Pool
SW-07001	Uvalda Ditch A
SW-07002	Uvalda Ditch B
SW-08001	South First Creek East Boundary
SW-11003	Havana Pond
SW-12001	Uvalda Ditch C
SW-12002	Uvalda Ditch D
SW-12003	Rod and Gun Club Pond
SW-12004	Storm Sewer
SW-24003	North Bog
SW-24004	First Creek North Boundary
SW-30001	North Plants
SW-30002	First Creek near North Plants
SW-31001	First Creek Toxic Storage Yard A
SW-31002	First Creek Toxic Storage Yard B

3.3.3 Surface Water Quality Monitoring Methods

Specific collection or monitoring methods are described in the Field Procedures Manual. The Analytical Procedures manual contains the certification procedures and laboratory data forms. All collection procedures and analytical methods will comply with the USATHAMA QA Plan.

Stream samples will be obtained by integrating samples collected over the cross sectional area of the stream. Where the stream is too small to permit this, the samples will be collected from the center of the channel just below the stream surface. Lake or pond samples will be collected as grab samples from near the shoreline.

Field parameters (pH, specific conductivity, alkalinity, and temperature) will be measured with field instruments that will be calibrated against known standards.

Surface water samples will be collected with a stainless steel dipper, a clean sample container, or if appropriate, directly with the sample bottle. Samples for organic analysis (VOA, DBCP, DCPD, organochlorines, and organosulfurs) will be collected in amber glass bottles with Teflon (R) - lined caps. Samples for inorganic analysis (chloride/fluoride, total metals-unfiltered, dissolved metals-filtered, and nitrates) will be collected in polyethylene containers. Dissolved metals fractions will be filtered in the field using 0.45 micron nitrocellulose or cellulose acetate filters. Both metals fractions will be fixed with dilute nitric acid to a pH of 2. The nitrates fraction will be fixed with sulfuric acid added to a pH of 2. All sample bottles will be placed on ice in a sample cooler immediately upon filling.

Samples collected in the automatic sampler will be retrieved immediately after the surface water team reaches a station during a high flow event. These samples will be handled in the same manner as those collected manually.

In order to characterize the influence on water chemistry of contaminants originating at RMA, it will be necessary to determine the quality of water entering RMA. For this reason, Gas Chromatography-Mass Spectroscopy (GC/MS) (EPA 624/625) analyses will be performed in addition to the analyses for the target parameters on surface water samples collected on all inflows in the south and southeast boundaries of the property, and on the single outflow of First Creek at the north boundary (see Table 3.3-2). The GC/MS method provides confirmation of contaminant levels detected by other methods and is capable of indicating the presence of non-target compounds. In addition, GC/MS analysis will be performed on approximately 10 percent of the samples collected from the remaining sites located within RMA. These samples will be selected following a review of historical monitoring and based on field conditions.

3.4 Sediment Transport

Sediment transport is a potential pathway for contaminants in the surface water system at RMA which has been identified in the RI Program. The sediment loading in the drainages on RMA is a significant factor influencing the aquatic habitat and the evolution of the channels. Increased loading of the streams as a result of remedial activities may significantly modify the characteristics of the drainages (e.g. silting) and result in the deposition of sediments downstream of RMA.

Contaminants may be transported through the surface water system adsorbed onto sediment particles which move as suspended or bedload in the drainages. Limited data exist to evaluate the magnitude of the flux of low solubility contaminants such as heavy metals, pesticides and semi-volatile organics through the surface water system.

As a result of the potential importance of sediment transport and the limited amount of available information, a program has been developed to verify the conclusions developed in the RI Program. The program is limited to First Creek as this is the most likely location for fluvial sediment migration on RMA and for these sediments to move off-post. The objectives of the program are to:

- Obtain additional baseline data on the transport of suspended and bedload sediments in First Creek; and

- Monitor the chemistry of the mobile sediments to enable a preliminary assessment of the significance of the migration of adsorbed constituents as a contaminant pathway on RMA.

3.4.1 Sediment Quantity

In order to monitor the sediment load of First Creek both suspended and bedload samples will be collected at the surface water sampling locations at the upstream and downstream boundaries of RMA (see Plate 2.2-1). Samples will be collected on a monthly basis to enable an assessment of seasonal changes in sediment loading. Samples will also be collected during two or more high flow events, in conjunction with the measurement of discharge during these events (see Section 3.2).

Sampling Equipment

Suspended sediment samples will be collected using a hand-held, depth-integrating sampler (US DH-48) described in detail by Guy and Norman (1970). During high flow events when it will not be possible to wade in First Creek, an alternative sampler (e.g. US DH-49) may be employed.

Mobile bed materials will be collected for chemical analysis using a hand held sampler, such as the BMH-53 (Guy and Norman, 1970), which is suitable for use in a stream that can be waded or accessed during high flows. The BMH-53 sampler uses a piston inside a cylinder to create a partial vacuum above the material being sampled, which retains the sample in the cylinder when it is removed from the stream bed. Bedload mass transport will be measured using a Helley-Smith bedload sampler.

During this initial program it is not proposed to install permanent equipment. If the need for it has been demonstrated and sufficient information is available on the streamflow and sediment characteristics to enable the design of a sediment monitoring station permanent equipment may be installed. Hand-held sampling devices are more easily adaptable to a range of hydraulic and sediment conditions.

Sediment Sampling Techniques

Sediment samples will be collected from First Creek near the upstream and downstream boundaries of RMA (Plate 2.2-1). As the program progresses these stations may be moved to optimize their siting. Specific concerns which will be addressed in the selection of the final station locations will include the stream geometry and the accessibility of the station during high flows.

Suspended and bed sediments will be collected from a minimum of three, equally spaced verticals across the stream section. Adjustments to the number of verticals employed at each section will be made on the basis of streamflow and channel conditions. The sediment concentrations obtained in this manner can be combined with the flow rate measured at the section to compute the sediment discharge. The Equal-Transit Rate method (FIASP, 1963) will be used to calculate sediment discharge due to the lack of current information on the streamflow characteristics of First Creek.

During an initial site visit, an inspection will be made of the First Creek channel to identify potential sources of sediment (e.g. gullying, construction activity, non-point sources). This inspection will be repeated on a quarterly basis. The results of this survey will be summarized in the Annual Technical Report. Recommendations will also be made in this document as to the need for a more rigorous evaluation of the sediment sources.

Details on the field procedures that will be employed in the measurement of the fluvial sediments are presented in the CMP Procedures Manual.

3.4.2 Sediment Quality

A second objective of this program will be to evaluate the significance of sediment transport as a mechanism for the transport of adsorbed contaminants. Consequently, samples of suspended and bed sediment samples will be retained, on a quarterly basis and during two high flow events, for chemical analysis. The procedures used in the collection, handling and shipment of these samples are detailed in the CMP Field Procedures Manual.

Analysis of fluvial sediment samples has not been conducted during previous monitoring programs. Consequently, there are no USATHAMA approved procedures for the analysis of these samples. This program will be conducted without such certification, using EPA approved methods (such as modified Methods 8240 and 8270 for use with small volumes of sediment), in order to evaluate the need for the approval process by USATHAMA.

It is anticipated that the bed sediment samples will be treated as soil samples for preparation prior to analysis. Similarly, the suspended sediments will be treated as soils if a sufficient volume of sample can be collected. If an inadequate mass of the sample is available, then sample preparation will be conducted using approved EPA methods for the handling of water samples containing suspended solids.

The sediment samples will be analyzed for the suite of target compounds (Table 3.3-1) with some exceptions. Volatile organic compounds are unlikely to be adsorbed onto the stream sediments, consequently Analytical Methods 601, 602, and 624 will only be employed during the initial analytical event unless these compounds are detected.

At the completion of this program an evaluation will be made of the potential significance of sediment transport as a mechanism for contaminant migration on RMA. Recommendations will be developed and integrated into the Annual Technical Report for additional investigations of sediment transport, if necessary.

3.5 Ground Water/Surface Water Relationships

To complete the monitoring of the pathways by which contaminants may be moving off the RMA, it is important to assess the relationship between the surface and ground-water systems, and specifically the potential for the discharge of contaminated ground water to surface water. Additionally, the estimation of recharge to the ground water is very important. It is probable that a portion of the ground water beneath the RMA is locally derived from within the RMA. From the current understanding of the ground water and surface water relationships, two regimes have been identified for monitoring. These are First Creek, and the area around the Lakes.

3.5.1 First Creek

Within the First Creek drainage the relationship between surface water and ground water will be investigated. The purpose of this program is to locate stream reaches where the stream is gaining ground water or recharging the ground-water system. Locating areas where ground water discharges to the stream will allow later stream water quality sampling and an evaluation of contaminant discharge to surface water which could leave the RMA.

First Creek is the only drainage system where discharge and recharge could both reasonably occur (Resource Consultants, Inc., 1982). Other drainages on RMA may be recharging ground water, but it is likely that no ground water discharge occurs. Monitoring of other drainages, such as the interceptors, could be accomplished if the monitoring on First Creek suggests that additional monitoring for recharge is warranted. First Creek is the only drainage way which traverses the RMA and serves as a natural discharge path. It passes above and near many of the contaminated aquifer units. Though First Creek may not pass near enough to major contamination sources to connect with the plume(s) it is the most likely route for movement of contaminants off the RMA in surface water.

Prior to initiating the First Creek monitoring a review will be made of the data collected by previous contractors. That information is currently being gathered by the PMO, and will be evaluated in the RI/FS water media report.

The methodology for recharge/discharge monitoring on First Creek is outlined below. The field procedures to be employed are contained in the Field Sampling Procedures Manual. After review of data from previous investigations, ten locations will be chosen for measuring stream discharge. The locations will be identified on the basis of access, alluvial geology, stream morphology, proximity to source areas and spatial distribution. Sampling locations will begin near the southern boundary and end as far to the north as the stream is flowing.

Monitoring to evaluate surface water and ground-water interactions will be performed during a period of constant base flow. It will be important to conduct the monitoring during a low flow period because storm runoff would mask the subtle differences suspected between recharge and discharge. Base flow will be estimated after the previous raw data have been reduced and evaluated. At each of the station locations, discharge will be measured using a pygmy meter, a portable Parshall flume or other appropriate techniques. Inflow to First Creek from tributary and other sources, eg. North Plants, will also be measured.

Field data consisting of station locations and flow readings will be returned to the office for reduction and analysis. The discharge at each location will be calculated. From the calculated discharge data an interpretation will be made as to whether differences between the stations represent recharge or discharge.

Water quality samples will be collected during baseflow conditions from stream reaches that are judged to be mostly locations of ground-water recharge to the stream. The objective of this activity is to evaluate whether First Creek is transporting contaminated ground water off RMA. Samples collected from reaches that appear to be receiving ground-water flow will be analyzed for all target analytes.

The results of this investigation will be summarized in the Annual Technical Report. If the data indicate, the report will identify the areas where surface water and ground-water interactions can be monitored. Recommendations might include the installation of wells near the stream to further assess the stream and ground water interaction, the collection of additional ground-water and surface water samples, and the installation of permanent monitoring stations, if appropriate.

3.5.2 Lakes

At the lakes, the stage of each lake will be monitored. The purpose of monitoring the lake stage is to record lake storage changes over time. This information may be used to evaluate lake and ground-water interactions. Estimation of aquifer recharge may be a critical element in the design of future remedial activities. These data may also be useful in the operation of the PMO's Surface Water Management Plan.

The stage of each of the lakes has been monitored under previous RMA monitoring programs. Staff gages exist on Upper Derby Lake, Lower Derby Lake, Lake Ladora, and Lake Mary. Havana Pond has been equipped with a Stevens Type F recorder. Through existing stage volume relationships, volume changes have been incorporated into water balance calculations for each of the lakes. These past calculations have been tabulated but have not been incorporated into any reports.

The first activity will be to review the previous calculations for mass balance which contain the lake volume determination. From that review, improvements in the monitoring program may be recommended. The reading of the staff gages will occur on a weekly basis in conjunction with the servicing of the Stevens recorders on the other gaging stations on the network. The weekly readings will be entered into the mass balance calculations for a monthly reporting period to be compiled at the end of the first year's program.

In order to evaluate the relationship between the lakes and the shallow ground water system, water level fluctuations in a limited number of wells around the lakes will be monitored on a weekly basis. Initially the following 12 shallow wells have been selected for inclusion into the program:

Wells
01021
01024
01027
01049
01069
01070
02001
02008
02020
02034
02050
02052

This list may be revised, notably through the inclusion of shallow wells installed by Shell in the vicinity of the lakes into the program.

Pan evaporation data will be collected from the literature for the Cherry Creek Reservoir Station located to the southeast of the RMA. An evaluation of the need for an onsite evaporation pan will be made. An onsite pan could improve the accuracy of evaporation data at the RMA, but the advantages of such an improvement could be negated by the inherent errors involved in the measurement of other portions of the water budget.

In the lake, mass budget calculation, evaporation is one of the components along with precipitation, transpiration, infiltration, inflow, outflow, and resultant changes in storage. Typically, all but one component is measured and the algebraic equation is solved for that component. Infiltration and transpiration are difficult to measure directly. Therefore, if the equation is being solved for infiltration as may be the case during remediation, the accuracy of the other components becomes important. During the first year of the CMP, an assessment will be made of the potential errors in the elements of the water budget. Recommendations will be developed to improve the measurement accuracy for each element.

The products from this activity will be the monthly water budget for each of the lakes. These monthly data will be assembled along with the raw data into the Annual Technical Report. Precipitation, evaporation, transpiration, inflow, outflow and infiltration will be assessed for the period of the water budget calculation. The recommendations section will, if warranted, describe changes to be made to this monitoring activity (such as continuous recording systems) for improving the estimate of infiltration and recharge to the underlying aquifers. The storage volume of the lakes will be made available to the PMO for input into their Storm Water Management Program. This information can be provided on an as needed basis.

4.0 LABORATORY ANALYSIS PROGRAM

The objective of the laboratory analysis program is to provide the PM RMA with reliable, reproducible, and legally defensible surface water quality data for contaminants at RMA. The analytical program will initially be a continuation of that employed in the Task 44 Monitoring Program. It incorporates surface water analyses, the Target Analyte list, a GC/MS program, and analysis of stream sediments.

4.1 Target Analytes

The surface water quality samples which will be collected under the various tasks described in this technical plan will be analyzed for the parameters listed in Table 3.3-1. This list of chemical parameters is referred to as the Target Analytes. The Target Analytes list has been developed over the years of investigation at the RMA to represent the major contaminants of concern. The methodologies and detection limits are as specified by USATHAMA. Specific analytical methods are discussed in detail in CMP Analytical Procedures Manual.

The defensibility and technical quality of data generated in this program will be assured by documenting all of the analytical procedures, and requiring all data to exceed minimum analysis method requirements with respect to instrument calibration. Sample preparation, materials shipping, handling, and Chain-of-Custody procedures will follow the protocol outlined in the Quality Assurance/Quality Control Manual for the Comprehensive Monitoring Program.

4.2 GC/MS Analysis

In order to further characterize the quality of water flowing onto and off of the RMA it will be necessary to analyze some samples by the Gas Chromatography-Mass Spectroscopy (GC/MS) analytical technique. This technique will provide confirmation of target compound contaminant levels detected by gas chromatography if levels are sufficiently high to be detected by GC/MS. GC/MS is capable of indicating the presence of non target analytes if high enough concentrations are present. With the GC method, if high enough concentrations are not present to enable the detection of a specific compound, then the detection of the chemical compound class is usually possible. The GC/MS analyses will be concentrated along the southern boundary. For QA/QC additional samples will be collected and analyzed. These samples will be from the routine program and will be performed on 10% of the samples.

4.3 Sediment Analysis

Although sediment transport has been identified in the RI Program as a potential pathway for contaminant migration, analysis for contaminants adsorbed on stream sediments has not been conducted under previous water quality monitoring programs. The sediments which will be collected can be categorized into bed load and suspended load. The bed load samples will be treated as soil samples for analytical preparation prior to analysis. The suspended samples will be treated as soils if enough sample can be collected. If only small amounts of sample can be collected, then the sample preparation will be done by approved EPA method 160.2 for handling water samples containing suspended sediments. It is our understanding that the Army does not have approved methods for suspended sediments. It is important to carry out this analysis ahead of any standards procedure changes in order to assess if there is the potential for movement of contaminants on or off the RMA through the transport of fluvial sediments. If the potential appears great, then the recommendation will be made to the Army to initiate the standards approval process.

Sediments will be analyzed for the target analyte list with some exceptions. It is probable that volatile organic compounds will not be adsorbed onto the fluvial sediments, so Methods 601, 602 or 624 will only be performed after the initial round of analyses, if these compounds are detected.

5.0 SURFACE WATER DATA EVALUATION

The purpose of the Surface Water Monitoring Element of the CMP is to monitor surface water quantity and quality in order to verify the data collected, and the conclusions drawn in the RI Program.

In order to meet these objectives, it will be necessary to compile and evaluate the information generated during the CMP and previous monitoring programs. An annual report will be completed in order to evaluate the relationships between water quality, the sources of contamination on RMA and contaminant pathways.

Information generated by the CMP Surface Water Element will be presented in an annual technical report. The initial report will include:

- background information;
- discussions of all work performed during the previous year;
- compilation of field, laboratory, and office data developed under the program;
- the results of interpretive efforts;
- conclusions drawn during the program;
- recommendations for changes in the scope of work for the next year;
- recommended modifications to the monitoring system; and
- recommendations for changes in the operation or monitoring of specific remedial actions.

In addition, a data summary update will be presented in letter form on a quarterly basis. A more detailed discussion of the contents of the Technical Report is presented in the following sections.

5.1 Presentation of Surface Water Data

Both tabular and graphical presentations of surface water data will be provided, together the compiled original data charts. Tabular presentations will include:

- A summary of flow rates for each monitoring station on a monthly basis presented in the format adopted by the US Geological Survey (USGS);

- A summary of surface water chemistry summarizing concentration variations among monitoring stations over time.
- A summary of lake water budget elements.

Graphical presentations will include:

- Stage-discharge relations at each monitoring station.
- Annual hydrographs of the flow at all active monitoring stations.
- Areal plots of concentrations of selected contaminants at monitoring stations showing detectable concentrations on an RMA base map that includes surface water features.
- Plots of selected contaminant concentrations at each monitoring station.

5.2 Surface Water Quantity Analysis

The surface water quantity portion of the annual CMP report will include the following:

- The results of the evaluation of surface water data generated during previous monitoring programs.
- A comparison of surface water quantity data obtained during the CMP to that acquired from previous investigations.
- A summary of all major maintenance and modifications performed, and equipment acquired.
- A discussion of any adjustments to the historically derived stage-discharge curves based on stream-flow measurements obtained during the CMP,
- A discussion of any adjustments to the historically derived stage-volume curves based on an evaluation of the original methodology, or discrepancies between the original survey data and field checkpoints.

- A discussion of the preliminary results of the investigations of the relationship between surface and ground water conducted on First Creek and the RMA lakes, and if warranted, the recommended technical approach for further investigation.

5.3 Surface Water Quality Analysis

The surface water quality portion of the annual report will include the following:

- A discussion of surface water quality data obtained during the CMP compared with that acquired from previous investigations.

- A discussion of surface water quality data as it pertains to the First Creek study.

- A discussion of any recommended alterations in sampling locations, frequency, analytical parameters, equipment, and methodology.

5.4 Sediment Transport Analysis

- A discussion of the methodology and results of the sediment sampling program.

- A discussion of the methodology and results of the investigation to estimate the volume of stream sediments moving through the surface water system.

- A discussion of relevant refinements to be included in the sediment sampling program if warranted by the results of the initial phase of this investigation.

5.5 Historic Overview of Surface Water Features

A literature search will be conducted to compile a brief chronology of the evolution of surface water features at RMA. This would begin with a characterization of natural streams and ponds and continue with a description of the ditches, impoundments, diversions, sewers, and other alterations which have influenced the surface water system. The RMA Resource Information Center and Facilities Engineer's Office are expected to be the primary source of information for this chronology.

The first annual, technical report on the surface water element of the CMP will include an overview of the surface water features on RMA. Such a summary will provide a valuable resource for understanding the surface water systems on RMA. It will also provide a basis for evaluating the adequacy of the existing monitoring network in monitoring changes to the surface water system associated with implementation of the management program on RMA and other changes in water management upstream of RMA.

5.6 Contamination Assessment

The objectives of contamination assessment will be to determine if the conclusions drawn in the RI/FS study are correct and to evaluate the relationship between water quality, sources of contamination on RMA, and contaminant pathways.

Initially, data generated from the CMP and compiled from earlier programs will be evaluated statistically to identify significant trends. The statistical evaluation of historical surface water quality data will consist of tabulating and reviewing selected values. The frequency of analysis for a particular analyte at any given sample site will be determined as well as the number of detections, minimum and maximum values, and average concentrations. Further refinement or revisions of the statistical methods selected may be necessary as the historical data is reviewed. Water quality data from the upgradient boundary of RMA, for example, will be compiled and evaluated to assess the significance of off-post sources of contamination. Similarly, the results of the seepage investigation on First Creek and the relationship between water quality and discharge will be integrated to allow an evaluation of the interconnection between surface and ground water along this stream.

As the database of surface water data is expanded over several years, with verified data from other programs being integrated, it will have increased statistical significance and additional applications. Notably, discharge-frequency relationships, together with the relationship between sediment and water quality, and discharge can be developed for drainages on RMA. These statistical relationships may assist an assessment of surface water quality and point or non-point sources of contamination on RMA, and the role of surface water as a contaminant pathway.

6.0 PROCEDURES

In addition to sampling procedures discussed in Section 3.0 of this Plan, specific Surface Water Sampling Procedures are contained in the Field Procedures Manual for each of the sampling methods.

Laboratory procedures are discussed in the CMP Analytical Methods Manual.

Sample handling and Chain-Of-Custody Procedures are discussed in detail in the CMP Quality Assurance/Quality Control Plan.

7.0 QUALITY ASSURANCE

7.1 Field/Laboratory QA Program

The Quality Assurance (QA) program for surface water monitoring, sampling and analysis will be consistent with the QA Plan developed for the Comprehensive Monitoring Program. As designed, the QA Plan will ensure that valid and properly formatted data will be reported at the appropriate precision, accuracy, and sensitivity of each method used for PM RMA/USATHAMA sampling and analysis efforts. The plan is based on PM RMA/USATHAMA December 1985 QA program - 2nd edition requirements, as well as certified analytical methods submitted to and approved by PM RMA/USATHAMA. The QA Plan has been revised to include surface water sampling. Specific RMA QA/QC requirements for the surface water program are contained in the Quality Assurance/Quality Control Plan.

7.2 Specific RMA-CMP Requirements

7.2.1 Responsibilities

QA/QC responsibilities are discussed in detail in the Quality Assurance/Quality Control Plan.

7.2.2 Field Procedures

The Field QA Coordinator will report any discrepancies that cannot be resolved on-site to the Project QA Coordinator. Field sampling QA audits of the surface water monitoring and sampling procedures for the Comprehensive Monitoring Program will be conducted by the Field QA Coordinator every six to eight weeks. Samples must be collected in properly cleaned containers, promptly and properly preserved, and transported to the laboratory. The Comprehensive Monitoring Program QA/QC Plan describes the field procedures to monitor adherence to approved sampling QC practices.

Field operations to be audited include: 1) sample collection; 2) sample handling; 3) use of sample containers or collectors for the particular analysis; and 4) field documentation and chain-of-custody practices. To ensure that no contamination is introduced during the collection or transportation of the samples, field and trip blanks will be introduced into the sampling train. These blanks will be prepared in the lab using deionized water and sent to the field. Field QA blanks will be uncapped in the field during sampling to monitor potential contamination during the sampling process. Trip blanks will be carried with the samples during transport to monitor potential contamination during transport and shipment of the samples. To ensure that no contamination is introduced as a result of improper equipment decontamination, equipment rinse blanks will be collected. These field QA blanks will be collected at a rate of 5% each of the total samples. In addition duplicate samples, at a rate of 10% of the total samples, will be collected to monitor the consistency of sampling procedures.

As part of the audit procedures; the Field QA Coordinator will monitor sample collection. A Field Sampling Audit Checklist will be completed, and a QA Field Audit Report submitted to the Project Manager within 30 days of the QA field audit trip. Any procedures not in compliance with PM RMA/USATHAMA and Stollar sampling QC practices will be identified to the Project Manager within 24 hours of observation, and proper corrective actions will be taken. Specific QA/QC procedures are discussed in the CMP QA/QC Plan.

Details of the QA program for the field activities to be conducted under this element are detailed in the Monitoring Program QA/QC Plan. As designed, the QA plan will ensure the production of valid and properly formatted documentation of the field procedures.

Field files will be maintained for each site sampled. These files will contain all information pertinent to the collection, custody and shipment of the samples. These files will be reviewed by the Field QA Coordinator within one week of sampling.

7.2.3 Laboratory Analytical Controls

Daily laboratory QC of the analytical systems ensures accurate and reproducible results. Careful calibration and the introduction of control samples (control spikes and blanks) are prerequisites for obtaining accurate and reliable results. Instrumental and sample lot controls are described in the Comprehensive Monitoring Program QA/QC Plan and the approved certified method write-ups.

The Laboratory Coordinator will monitor the analytical controls. Failure to pass the instrumental calibration or control sample QC criteria represents an out-of-control situation. Written notification of the QC failure will be provided to the Project Manager, and proper corrective action will be implemented by the Project QA coordinator. Specific discussions of analytical controls are contained in the QA/QC Plan.

7.3 Surface Water Monitoring QA Program

The CMP Field Procedures Manual for RMA is Stollar's comprehensive procedures document which addresses all of the field requirements. The sampler will be required to follow the procedures, and the Field QA Coordinator will conduct frequent inspections to verify that they are being followed. In addition, manual QC checks will be performed by the Chemical Analysis Supervisor and the laboratory QA staff in each laboratory.

Each laboratory will maintain a chemical data file for each lot of samples analyzed which will include: 1) copies of logsheets of sample receipt; 2) relevant analysts' notebook pages; 3) extraction logsheets; 4) instrumental logsheets; and 5) raw data sheets including complete chromatograms, calibration curve data, calculation worksheets, and final data.

The Comprehensive Monitoring Program QA plan details the reviewing and reporting functions of the Project QA Coordinator. A formal review and sign-off sheet will accompany all chemical analysis results for each completed Army lot of samples. It is the responsibility of the laboratory QA staff to check the sign-off sheet periodically to ensure that the review process is complete.

During the active conduct of chemical analyses, the laboratory QA staff will submit a QA Program Status Report upon completion of each analytical lot to PM RMA/USATHAMA. This submittal will include a hard copy of the lot QC charts. All points which indicate an out-of-control situation will be evaluated and explained, and necessary corrective action to prevent recurrence described.

8.0 DATA MANAGEMENT

General data management procedures that apply to all phases of the CMP are addressed in the general Data Management Plan. This section deals with the procedures specific to the management of data generated pursuant to the Surface Water Monitoring Plan's objectives.

8.1 Analytical Data

Water quality samples requiring laboratory analysis will be shipped under chain-of-custody to Datachem, Inc. and Enseco-Cal Labs. The laboratories will log the samples in a logbook specific to the CMP program and review the sample tags and accompanying field chain-of-custody record for agreement. Any discrepancies will be noted in the logbook and rectified by contacting the Site Manager and/or QA Coordinator upon receipt of the samples. The laboratories will be responsible for assigning the samples to the various analyses as stated on the field chain-of-custody and ensuring that they are conducted within the guidelines of USATHAMA certified methods.

Laboratory personnel will be responsible for the coding of the results of analyses into format prescribed for use in the Installation Restoration Data Management System (IRDMS). Data entry and initial data verification will be conducted by laboratory personnel utilizing the PC-based IRDMS programs provided by USATHAMA. Files will be transferred to the Data Management group in Denver via floppy diskettes; copies of the data entry coding forms will also be sent for filing in the Denver office. Acceptable data will be uploaded by the Army's Data Management group into the files serving as the final repository for the data generated under the Rocky Mountain Arsenal IR program. Unacceptable data will be returned to the Stollar Data Management group for correction.

The map records in the IRDMS files for locations of existing stations will be verified by the Stollar team. New sampling locations and existing locations which have previously been surveyed will be precisely located by Stollar contracted surveyors. This information will be provided to the QA Coordinator and used to code map records for entry onto the IRDMS. Data entry and initial data verification will be conducted by the Data Management group. Map data will flow through the IRDMS in the same fashion as described above for the analytical results.

8.2 Surface Water Quantity Data

The need has been identified to establish a comprehensive data base drawing from all surface water studies performed throughout the history of RMA. The Program Manager's Office is currently compiling the raw data from all available sources that pertain to the RMA surface water system. We further understand the Stollar team will be involved with the evaluation, reduction, the organization of this information into an electronic data base format. This information will be critical in confirming stage relationships, evaluating monitoring station utility, evaluating proposed remediation actions, and establishing the impacts of future actions on the surface water environment.

Field measurements and observations, and strip charts from the Stevens recorders, will be reduced and analyzed by the Stollar surface water team. Hydrologic information generated from field data will be arranged in a format identical to that used by the USGS Water Resources Division for published streamflow record. These tabulations will include a unique station identifier; surveyed location and elevation for each station; average daily flows; daily high and low flows; and instantaneous high flows.

The reduced data will be entered into a computer data base. A copy of this data base will be transferred to the repository managed by Ebasco Services Incorporated. A second copy will be retained by the Stollar surface water team for statistical analysis of the hydrologic data.

During the reduction of the field data, all charts and coding forms will be signed and dated by the Stollar team member conducting the data reduction. As part of the CMP QA/QC program, the data reduction will be duplicated on 10% of the field data. If errors are noted an additional 10% of the field data reduction will be checked. Similarly, for QC purposes, 10% of the information entered into the data base will be checked against the original coding forms.

9.0 HEALTH AND SAFETY

9.1 Introduction

The Health and Safety Plan (HASP) for the CMP outlines the necessary information to conduct the surface water monitoring program in a safe and healthful manner to prevent chemical exposures and employee injuries. The information provided in this section serves only as a supplement to the HASP with information specific to the surface water monitoring program.

Activities associated with the surface water program will be performed in Sections 1, 2, 3, 4, 5, 7, 11, 12, 19, 24, 25, 26, 27, and 36 routinely. Other sections may be included depending upon remedial activities occurring or an increase in the scope of the program. These sections contain varying degrees of contamination which must be considered. In order to develop the most adequate HASP possible, an evaluation will be made of each sampling and monitoring station, so that specific programs can be developed. Overall procedures and methods are outlined in the following sections.

9.2 Responsibilities

9.2.1 Health and Safety Supervisor (HSS)

The responsibilities of the HSS are the same as in the HASP for the CMP. The HSS will be responsible for advising the surface water personnel of potential hazards in the areas they will be working in and assigning levels of protection for the associated hazards. The HSS will determine the necessity of air monitoring during the activities of this program.

9.2.2 Surface Water Monitoring Personnel

The surface water monitoring personnel will be responsible for coordinating their activities with the HSS. Every week they will be responsible for informing the HSS of their planned activities for the following week.

Personnel will be responsible for reporting any unsafe or potentially hazardous conditions which occur when performing their activities. They will also be familiar with the information instructions and emergency response procedures addressed in the HASP for the CMP. It is also their responsibility to conform to the rules and regulations of the HASP for the CMP.

9.3 Hazard Assessment

Activities associated with the surface water monitoring program will vary depending upon the characteristics of each station, as well as current weather and streamflow conditions. The sections that pose the greatest risk of potential chemical exposure include Sections 1, 2, 36, and 26. These sections represent the South Plants area (1, 2), Basin A (36), and Basin F (26), and include eight of the surface water monitoring stations.

The South Plants area has various chemical hazards present in the soils that may become airborne and pose an inhalation hazard or a skin adsorption hazard. These chemicals include chlorinated pesticides (aldrin, dieldrin), solvents (benzene), and heavy metals (lead, mercury, arsenic). The inhalation route of entry is the greatest hazard, on high wind days or very hot summer days. If the weather conditions are present to create an inhalation hazard then respiratory protection should be considered.

Normally however, respiratory protection would not be required. If the possibility exists for skin contact with contaminated materials (notably water), then chemical protective clothing must be worn which protects against the compounds of concern. More in depth toxicology on the various chemicals can be found in the HASP for the CMP.

The Basin A area was used as a disposal basin for production operations in South Plants. Waste from chemical agent production and pesticide production were disposed in the basin. The basin is dry and unvegetated over much of the area. The main hazard would be from inhalation of airborne particulate matter in the basin, which may contain heavy metals (lead, mercury, arsenic) and pesticides (aldrin, dieldrin). Invasive activities would also present a potential chemical agent hazard. However, invasive activities are not anticipated in this program, but they may be occurring in other sections of RMA as part of other programs. Surface water personnel should be familiar with Appendix C of CMP HASP if a chemical agent hazard is present. When working in the Basin A region, Level C or B will be required when airborne dust is likely to be present.

The Basin F area was used as a disposal basin for chemical waste from all the production facilities in RMA. The Basin no longer contains contaminated liquid waste. A clay liner has been applied to the floor of the basin with a clay cap on top of the waste pile. In January of 1989, the requirement for personnel to wear respiratory protective gear while working in certain areas in the vicinity of the basin was eliminated.

The major hazards associated with the surface water monitoring activities are likely to be skin and eye contact with contaminated water as well as physically falling into a body of water. As all surface water sampling will be done from the edge of the water body and not from a boat, the falling hazards should be minimal. However, for surface water discharge measurements, which require entering the stream personnel will be secured with a lifeline.

9.4 Personal Protective Equipment

The minimum levels of protection for personnel involved in field activities as part of the surface water element of the CMP will be as follows:

- o Section 36 - field personnel will wear modified Level D protection while performing surface water sampling/monitoring in Section 36.
- o Other areas - field personnel will wear level D protection at all other sampling monitoring sites. Protection will consist of inner and outer rubber gloves, steel toe and shank rubber boots, goggles for eye protection, and cotton overalls. Respirators will be readily available.

All sampling and monitoring efforts will be performed in teams of two. Before commencing activities, field personnel will check in at the safety trailer. While wearing Level D protection, samplers will avoid submerging their hands in water so deeply that water drains into the top of the gloves. Gloves should be taped at the wrists in modified Level D protection. Levels of protection will be upgraded if the Safety Officer deems it necessary.

Respiratory protection may be required in Sections 1, 2, 26, and 36. Full-face air purifying respirators with GMC-H or pesticide cartridges will be used for the majority of work requiring respiratory protection. When the Basin F remediation programs begins, any work near that project will require compliance with the applicable HASP. This may require the use of supplied air respirators or self-contained breathing apparatus.

9.5 Decontamination

Decontamination will be required at the end of the work day by all personnel. This includes decontamination and disposal of protective clothing. The personnel will also be required to wash their hands and face prior to eating, drinking, smoking, or leaving the site. Showers will be mandatory for personnel if working at RMA when Level C or B was required.

Equipment decontamination control will be exercised prior to storing, calibrating, or moving equipment from one section to another. Vehicle decontamination must be performed when driving in Section 36. The vehicles driven in Section 36 must be driven on the service access roads on the perimeter of the section to the decontamination pad in the southeastern corner of Section 36. The vehicles tires, undercarriage, and exterior must be thoroughly steam cleaned at the decontamination pad prior to driving outside of Section 36.

9.6 Emergency Procedures

Personnel will be familiar with the Emergency section of the CMP HASP. All injuries, irrespective of seriousness, will be reported to the Health and Safety Supervisor immediately. Any conditions that may create a health or safety hazard will be reported to the Health and Safety Supervisor when they are observed. The Health and Safety Supervisor will then evaluate the condition for corrective action that may be required.

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APPENDIX A

COMMENTS TO TECHNICAL PLAN VERSION 2.2

Part I: Comments of and Responses to United States Environmental Protection Agency Region VIII

RESPONSES TO UNITED STATES ENVIRONMENTAL PROTECTION AGENCY COMMENTS ON THE COMPREHENSIVE MONITORING PROGRAM DRAFT FINAL TECHNICAL PLAN FOR SURFACE WATER

APRIL 1989

Comment 1: Page 5, expand the text to further explain the isolation of Basin F from surface runoff. Will runoff onto the Basin be monitored as part of the CMP or as part of the IRA for the Basin?

Response: The text has been modified to further explain the isolation of Basin F from surface runoff.

Comment 2: Page 8, third paragraph, was flow diverted from the Sand Creek Lateral to Basins C and B or to the Sand Creek Lateral from the basins. Please clarify the text.

Response: The text has been modified to clarify the relationship of flow between the Sand Creek Lateral and Basins B and C.

Comment 3: Page 10, Lake Mary, second paragraph, expand the text to specify where the flow now terminates since the Section 3 embankment has been breached and also which overflow basin receives runoff during high rainfall events.

Response: The text has been expanded to clarify where outflow from Lake Mary terminates in Section 3.

Comment 4: Page 10, the current water levels in the lakes and overflow basins and the frequency of water level measurement should be presented in this report, as a baseline for future work.

Response: A discussion concerning the measurement of water levels in the lakes and ponds is presented in Section 3.2.3 (Surface Water Data Acquisition). Table 3.2.1 describes the frequency of monitoring activities for these areas. A review of historical stage data in comparison to stage measurements made during the first year of the program will be presented in the first year Annual Report.

Comment 5: Page 11, Basin A, second paragraph, the text should include a rough estimate of the extent of local ponding as a percentage of the total surface area. If estimates of the infiltration rates, seasonal effects, volume, and depths of ponding have been made, these should also be presented.

Response: Information pertaining to ponding in Basin A is very limited. Information presented in the North Central Study Area Report (Ebasco, 1989) will be used to update the Basin A discussion in Section 2.1.4.

Comment 6: Page 13, Section 2.2.1. This section contains numerous instances where potential improvements or repairs to a particular gaging station are mentioned, but it is not clear whether the improvement/repair is actually to be performed (see page 14, third full paragraph; page 16, third paragraph, page 17, first paragraph; page 20, first and fifth paragraphs). The text should clearly state what improvement/repairs are to be made to the stations.

Response: Section 2.2.1 presents a preliminary evaluation of the condition of the gaging stations prior to initiation of Surface-Water CMP field activities. Those stations that improvements or repairs have been recognized as necessary and would be implemented are part of the program are indicated. Also in this section, potential improvements or repairs that might be undertaken are also outlined. These possible changes to the stations will be further evaluated as part of the activities of the first year of Surface Water CMP before any action is taken. Completed improvements or repairs to the gaging stations will be discussed in the Surface Water Annual Report.

Comment 7: Page 26, how will this program eliminate "the uncoordinated movement of surface water on RMA"?

Response: The text has been expanded to explain how the Surface Water Management Program will eliminate the uncoordinated movement of surface water on RMA.

Comment 8: Page 29, third paragraph. One of the surface water monitoring components listed is remedial action monitoring. However, this component does not appear to be specifically discussed in the plan. The text should clearly indicate where and why this component of surface water monitoring will be performed.

Response: The surface water program will be responsible for monitoring any impact that a remedial action implemented at RMA might have on the surface water system. No specific remedial actions have been designated for RMA, therefore no details concerning the monitoring of these actions are discussed.

Comment 9: Page 30, first paragraph. The text states that potential shortcomings which have been identified in the existing monitoring network (i.e. absence of monitoring stations in those basins with less well defined drainages) will be addressed during the initial phase of the CMP. However, this does not appear to be addressed in the subsequent discussion in the text. Are new stations being added? Clarification is requested.

Response: The reference in the first paragraph of Section 3.2.2 to the absence of monitoring stations in those basins with less well defined drainage is further elaborated on in the last paragraph of the section. This reference is made with specific regard to the construction of a gaging station to monitor overflow from Ladora Lake, which can flow into an undefined basin in Section 3. More specific recommendations concerning installation of a new gaging station to monitor flow from Ladora Lake will be made after the first year of the program and the new Ladora Lake spillway has been completed.

Also, subsequent to the writing of the Technical Plan, construction activities associated with the Interim Action Response at Basin F has effected local drainage. The need for a surface-water monitoring station for this small drainage is presently being evaluated.

Comment 10: Page 36, third full paragraph. The text should indicate where it is anticipated that the 15 storm event samples will be obtained.

Response: The text has been expanded in Section 3.3.2 with the addition of Table 3.3-3 to indicate the potential locations where the additional 15 annual and storm event samples may be collected. Plate 2.2-2 (Surface Water Sampling Locations) indicates where these sampling points are located.

Comment 11: Page 41, what criteria will be used in the selection of the other 10 percent of the samples for which GC/MS will be used:

Response: As indicated in the text in section 3.3.3, GC/MS provides confirmation of contaminant levels detected by other methods and is capable of indicating the presence of non-target compounds. The selection of those additional sites where GC/MS analyses will be conducted will be based on a review of historical monitoring and on field conditions. For certain locations the target analyte list may not be sufficiently comprehensive to include all potential contaminants. Consequently the target list will be supplemented by GC/MS analyses.

Comment 12: Page 44, how will the information on the mechanism of sediment transport be incorporated into future work? If this mechanism is a significant contaminant transport pathway, will the CMP also attempt to propose solutions to this problem?

Response: Because of the limited amount of data pertaining to the role of sediment transport in contaminant migrations in surface water at RMA, the CMP developed and will initiate a monitoring program. Initial efforts will evaluate sampling equipment, methodology, and analytical results. The program is designed to assemble the necessary data in order that an assessment of the significance of sediment transport as a mechanism for the transport of absorbed contaminants can be made. Based on the evaluations made during the program, the Feasibility Study (FS) Group will take further action if deemed necessary.

Comment 13: Page 47, to eliminate one of the water budget variables at a rather low expense, EPA recommends the development of onsite pan evaporation data.

Response: It is not anticipated that onsite pan evaporation data will be collected during the first year of the program. Evaporation information will continue to be collected from the Cherry Creek Reservoir Station.

Part II: Comments of and Responses to Colorado Department of Health

RESPONSES TO
STATE COMMENTS
ON THE COMPREHENSIVE MONITORING PROGRAM
DRAFT FINAL TECHNICAL PLAN FOR SURFACE WATER
APRIL 1989

Comment 1: In order to expand the available data for an adequate surface water management program and to evaluate the effectiveness of future remedial actions at RMA (Program Objectives, page 1), it is necessary to maximize data collection during the first year of the Surface Water (SWCMP). Identification of redundances in spatial and temporal sampling and resultant optimization of the monitoring program would then be based largely on evaluation of the chemical and physical data collected over the 12-month period. Many of the proposed changes to the SWCMP, presented in the following comments, reflect the need to increase the monitoring frequency during the first year of monitoring.

The Army states on page 24 of the SWCMP that, with the exception of the First Creek drainage, extensive water quality monitoring has not been conducted in the RMA drainage basins. However, a second reference (page 35) states that "Except for isolated areas... available surface water quality data suggest that contamination of surface water is not severe and is limited to a few classes of compounds." Deriving such a conclusion based on limited data is premature, since the results could also be due to a limited spatial and temporal sampling program. In order to determine the comprehensive extent of contamination of onpost and offpost surface waters, a more extensive data base must be developed during the first year of the SWCMP. At the conclusion of the year, the target analyte list and frequency of the sampling program can be reevaluated based on results of the compiled data.

Response: An extensive historical data base of surface water chemical analyses exists for the principle drainage pathways on RMA. Evaluation of the results of past monitoring efforts has led to the development of the present sampling network. This network monitors the areas that have historically recorded analyte detections, as well as those areas that are important potential routes for contaminant migration in surface waters.

As indicated in Section 3.3.1, the previous sampling network established during Task 44 will be maintained so that a consistent water quality data base can be verified. Sampling of subordinate drainage pathways will not be undertaken unless a specific concern has been identified. For the first year of the surface water CMP, all water samples will be analyzed for the entire suite listed on Table 3.3.1. The need for changing this list of parameters will be evaluated after the first year of the program.

Comment 2: It is well documented that bottom sediments and surface waters in the Derby Lakes, Ladora Lake, and Lake Mary are contaminated. The SWCMP, however, does not include a sediment sampling program to monitor long-term trends in contamination. A comprehensive lake monitoring program must be developed, including monitoring temporal and spatial distributions of contaminants, to verify results of the RI program and to establish a database sufficient to evaluate remedial action performance. Lake sampling does not necessarily have to be performed as frequently as the sampling that scheduled for RMA streams and ditches. The State is willing to work with the Army to develop a SWCMP component for the RMA lakes.

Response: Historical sampling results presented in the Water Remedial Investigation Report (Ebasco, 1989) and Southern Study Area Report (Ebasco, 1989) showed no targeted analytes detected in any water samples collected from the lakes since 1984. No increase in the number or frequency of water samples taken from the lakes is anticipated at this time considering the historical water quality records. Creation of an extensive bottom sediment sampling program for the lakes is not in the scope of work scheduled for the Surface Water Element of the CMP. The present condition of lake bottom sediment contamination has been addressed in the Southern Study Area Report. Any further sampling of lake sediments, if warranted, would be conducted under the Feasibility Study Program.

Comment 3: Regarding the determination of stage-discharge relationships, the SWCMP states that stream gage measurements will be recorded weekly, whereas discharge measurements are to made only on a monthly basis. The State believes the comparison of a four-week gage level to a single point-discharge measurement may not result in a sufficient data set (12 observations) for the accurate calculation of stage-discharge relationships. Therefore, the State recommends that discharge measurements be made on a weekly basis coincident with gage recordings. With this measurement frequency, sufficient data to construct discharge rating curves for most monitored streams and ditches at RMA will probably be attained by the end of the first year of the SWCMP.

Response: The determination of a valid stage-discharge relationship at a gaging station is not highly dependant on a large number of discharge measurements. In creating a rating curve it is more important to have sufficient discharge data over a wide enough range of conditions such as ranging gage height and flow that less of the curve will need to be extrapolated. Albeit helpful in terms of verification of the curve that multiple discharge measurements show consistent stage-discharge relationships.

Discharge measurements will be made on a monthly basis as a part of seasonal surface water quantity monitoring, with additional measurements to be taken at high flow events and during spring and fall sampling events. In addition to scheduled monthly measurements, instantaneous discharge measurements will be obtained whenever unusual flow conditions are observed. Weekly stage measurements at the gaging stations consist of making staff gage readings and collecting continuous strip charge records of gage height from the Stevens Recorders.

Comment 4: The SWCMP proposes that suspended and bedload sediment samples at the North and South First Creek Monitoring Stations be collected on a monthly basis, whereas proposed chemical analyses of these sediments will only be analyzed four times (spring, fall, 2 storm events). The State recommends that sediment chemical analysis be performed for all RMA target analytes on a minimum bi-monthly basis, and coincident with sediment loading measurements during the first year of the SWCMP. Storm event sampling would remain as proposed. Establishment of this data base is important due to the absence of data prior to initiation of the SWCMP (page 44) and the sporadic nature of the data. After completion of the first year of the SWCMP, the sampling frequency and target analyte list can be reevaluated based on a much stronger data base than the one currently proposed. Since the data base will be used to determine potential onpost migration of contaminants from sources upgradient of RMA as well as potential contaminant migration offpost, its importance can not be overemphasized.

Response: The sediment sampling programs proposed for the first year of the surface water CMP is designed to obtain preliminary information with which to evaluate contaminant transport by sediments and recommend additional program needs if necessary. No data presently exists pertaining to the quantity of sediment being moved in the surface water system, nor under what flow conditions movement is occurring. Collection of bedload and suspended sediment samples for chemical analyses is scheduled to be performed during extreme conditions initially (i.e., high flow - spring and storm events and low flow - fall). This program is designed to characterize sediment movement and any absorbed contaminants at the end points of a range of flow conditions entering and leaving RMA. Increasing sampling frequency may be necessary, but will be evaluated after the initial program results are reviewed.

Comment 5: The purpose of the water quality and sediment sampling programs at North and South First Creek monitoring stations is to establish sediment and contaminant loading rates across RMA boundaries. The SWCMP proposes a very limited program for First Creek offpost. An expansion of this program must be developed for First Creek downgradient of RMA, with emphasis placed on exposure monitoring. Multiple temporal and spatial water and sediment samples must be collected in First Creek, from the RMA boundary to O'Brian canal and including the man-made pond in Section 14. The data base will augment historical data that is incomplete or sporadic, and can potentially be used to indicate areas of ground-water discharge to First Creek. The main function of the data collection program, however, must be to support offpost exposure assessment evaluations.

Response: A detailed evaluation of North First Creek Off-post was presented in the Water Remedial Investigation Report (WRIR) (Ebasco, 1989). Issues such as ground-water/surface-water interaction and contaminant migrations were assessed. The surface water CMP is designed to review the data collected and the conclusions drawn during the Remedial Investigation Program. After reviewing the WRIR assessment and the data gathered during the first year of the CMP, a determination will be made regarding the need for increased temporal and spacial water and sediment samples along the northern off-post section of First Creek. An additional study is being conducted as part of the Off-post Endangerment Assessment/Feasibility Study Program.

Comment 6: The Army states that "water quality will be monitored at the existing sampling stations" (SWCMP, page 1) which, according to ESE (ESE, Inc., 1986, referenced on page 21) and as indicated on Plate 2.2-2, included 37 water sampling sites. However, only 18 specific stations are listed in Table 3.3-2 for the SWCMP. Station numbers for the "15 Additional Samples" referenced in Table 3.3-2 are not provided, and therefore the scope of the surface water monitoring program is not clear.

A rationale for the exclusion of the non-referenced sampling points in the Sand Creek, Irondale Gulch, South Platte, Basin F, and Basin A drainages must be provided.

Response: Surface water sampling locations utilized by ESE in Task 44 were evaluated, resulting in retention of critical monitoring sites. Collection of samples at locations corresponding to previously established gaging stations will continue (Table 3.2-2). The 15 additional samples referred to in Table 3.2-2 have been designated for Annual and storm event sample collection. The potential locations where these samples may be collected are shown on Plate 2.2-2. A new Table 3.3-3 which will indicate the sampling location name will be provided in the revised Technical plan. Many of these sample sites display highly variable flow characteristics, generally only having flow following a major precipitation event. Therefore, these sites are not included with the list of stations which monitor the majority of surface-water flow on RMA.

Certain sampling locations previously designated as potential sampling sites by ESE as part of Task 44 were not incorporated into the sampling network. Reasons for not retaining these sampling locations include:

1) the sample site is continuously or nearly continuously dry;
2) a new site which provides better data has been substituted near the ESE sampling locations; or
3) There is no history of analyte detections at the ESE sampling site.

Comment 7: As has been pointed out by the Army, the First Creek drainage contains the major surface water conduit for potential offpost migration of contaminants. The Army dismissed contaminant detections along this conduit due to non-repeatable contaminant results (Eastern Study Area Report, page 3-89). Non-repeatable results likely are due to the limited sampling program undertaken to date. Sections 31 and 6 contain multiple source areas whose impact to First Creek have not been fully characterized. For these reasons, all prior sampling points on First Creek or First Creek tributaries must be included in the SWCMP. The importance of these stations is further elaborated in Table 1.

Response: Referring to Plate 2.2-2, it can be noted that CMP surface-water sampling locations SW-31002, SW-31001, SW-30002, SW-24001, SW-24003, and SW-24003 in the First Creek Drainage, correspond exactly or are near previously utilized ESE sampling sites. These locations are part of annual and storm event sampling network. Sample site SW-05001 which is designated for sampling 4 times a year, has been replaced by SW-08003 because of rerouting of First Creek.

Comment 8: For the reasons presented in Comment #1 the frequency of water quality sampling and GC/MS analyses must be increased during the first year of the SWCMP. Water quality sampling of the 18 stations listed in Table 3.3-2, in addition to those stations presented in Table 1 of this comment pack, must occur on a minimum bimonthly basis. All target analytes, indicated by the Army must be analyzed during the first year of the SWCMP, and GC/MS analyses should be increased to a bimonthly frequency for, at a minimum, stations (SW) 01-003, 36-001, 37-001, 02-002, and 24-001. The frequency of water quality sampling and GC/MS analyses for the lakes (01-004, 01-005, 02-001, 02-003, and 02-004) should be determined in concert with the lake sediment sampling program proposed in Comment #2.

Response: Increasing sample frequency to a bimonthly schedule would not contribute to the goals of the Surface Water CMP. The sampling program is designed to document seasonal and storm event variations in water quantity and quality at RMA, and to verify the data collected and conclusions drawn in the Remedial Investigations Program. Increasing sample frequency at several of the stations indicated by the State is not possible. Sample site SW-01003 (South Plants Ditch) is dry except during long duration, large precipitation events. Sampling location SW-02002 is in a section of Sand Creek Lateral where flow is manually controlled and infrequent. Sample sites SW-24001, SW-36001, and SW-37001 are part of the seasonal and storm event sampling networks, which have an extensive historical water quality data base.

As indicated in response No. 2, no historical target analyte detections have been documented for the water samples collected from the lakes in the sample programs conducted since 1984. Increasing sample frequency for the lakes is not anticipated at this time.

Comment 9: The State recognized the importance in defining sources of contamination upgradient of RMA and the resultant effect on RMA surface water contamination. However, one-half of the six samples proposed for GC/MS analysis are on the southern RMA boundary, arbitrary biases the GC/MS screening towards determination of upgradient contaminant sources instead of determination of RMA contaminant source effects on onpost and offpost surface waters.

Response: GC/MS analysis for sampling locations along the southern boundary of RMA have been designated in order to establish inflow water quality. GC/MS screening will aid in determining the background water quality of stream flow entering the Arsenal.

Once this has been established, contaminant contributions emanating from sources on RMA can be better evaluated. The number of sample sites on-post or downgradient off-post RMA requiring additional analyses (GC/MS screening) may need to increase in response to source investigations or changing conditions resulting from Interim Response Actions or Remedial Actions.

Comment 10: The following comments are made to improve the proposed ground water/surface water relationship investigation.

A) Selection of the ten stream-discharge locations in First Creek should be based on findings presented in the Offpost Operable Unit Remedial Investigation (See Figure 4.3-2). Similarities and/or differences in methodology and results from these two studies should be considered.

Response: The recharge/discharge study planned for First Creek as part of the CMP (discussed in Section 3.5.1) will take into account the findings presented in the Off-post Operable Unit Remedial Investigation (Figure 4.3-2)

B) Inflow of tributary waters to First Creek upgradient of each discharge station must be accounted for in discharge calculations.

Response: This concern has been noted and is discussed in Section 3.5.1. Tributary inflow will be considered in discharge calculations on First Creek.

C) Multiple measurement episodes of the ten locations are needed to establish a valid and comprehensive data base.

Response: Multiple measurement episodes will be conducted to discern seasonal changes in recharge/discharge occurring along First Creek.

D) Based on the gaining-stream segments shown in offpost RI Report Figure 4.3-2 described in comment 10A above, a minimum of three water quality sampling locations must be selected, and each location must be sampled a minimum of three times. Sampling times should be on a periodic schedule coincident with seasonal changes. Selection of sampling locations may overlap and satisfy certain data collection components listed in the surface water quality segment of the SWCMP.

Response: CMP surface water quality sampling locations SW-08001, SW-31001, and SW-30002 (Plate 2.2-2) occur within the gaining stream segments of First Creek presented in Figure 4.3-2 of the Off-post Operable Unit Remedial Investigation. These locations are scheduled for annual and storm event sampling (Table 3.3-2). Flow conditions at those sample sites will be further evaluated during the first year of the program. Increased sample frequency at these locations maybe necessary after evaluation of the data collected during the discharge/recharge investigation.

Comment 11: At another site investigation in the Denver area Harding Lawson Associates (HLA) documented major problems with the accuracy of bubbler water-level recording systems. At the request of EPA, HLA provided the Agency with a summary of the problems associated with the bubblers and recommended against using the devices in the field investigation. It is therefore requested that the Army work with its SWCMP contractor to determine if the use of bubblers (SWCMP, page 14) will compromise the quality of water-level data collection on RMA.

Response: Without any additional information regarding the bubbler water-level recording system described by HLA, it is assumed that the unit evaluated was a standard bubbler water-level recording system. This system is significantly different than the bubbler system to be installed at RMA. The standard bubbler water-level recording system consists of a specially designed servomanometer, servocontrol unit, gas-purge system, and recorder. It operates on the principle of nitrogen gas being bubbled slowly through a small tube and discharged freely into the stream through an orifice at a fixed elevation. The pressure in the tube corresponds closely to the head of water over the orifice. The pressure is transferred to a mercury manometer, one side of which is moveable. The movable reservoir is equipped with a float and sensitive double-acting switch. If the mercury pool moves because of a change in pressure on the fixed side, the switch is closed and the pool is returned to a null position by means of a servomotor. This motor drives a pen on a recorder chart so that a continuous record of stage is obtained.

The principal sources of error inherent in the standard bubbler gage include:

- variation in gas friction due to fluctuations in bubble-feed rate and temperature. Where long bubble tubes are used, the variation can produce error in recorded gage height;

- variation in the required bubble-feed rate with rate of increase in stage. During rapid rises in stage, the system response will lag behind the stream; and

- variation in weight of the gas column with stage. At installations where the pressure sensing system is high above the bubble orifice, and large fluctuations in stage occur, the variation in weight of the gas column with stage will cause the pressure sensed to be low at high stages.

The system to be installed at RMA is a <u>double</u>-bubbler system which operates on the same principal as the standard bubbler gage, whereby nitrogen is fed through a tube to an orifice where the nitrogen escapes into the water. The pressure in the tube corresponds to the hydrostatic head of the water. However, the physical configuration and operation of the double-bubbler system differs from the standard bubbler gage in the following ways:

- A transducer is used instead of a mercury manometer to sense the pressure in the bubbler tubes;

- A unique correction procedure, which utilizes two bubblers a known distance or pressure apart for continual transducer calibration, constitutes the double-bubbler system. Application of this technology provides for head detection accuracy of ±0.003 feet, even with an inexpensive, nontemperature-compensated transducer. The accuracy is independent of the transducer stability with temperature and time (it should be noted that the double-bubbler system was developed by the Agricultural Research Service (ARS), U.S. Water Conservation Laboratory in Phoenix, Arizona for accurate open channel flow monitoring associated with irrigation water management programs). This differs significantly from the standard bubbler gage equipped with a mercury manometer system that is temperature sensitive;

- the only moving parts in the double-bubbler system are solenoid valves utilized for switching between bubbler tubes (pressure lines) to accommodate the various pressure readings with a <u>single</u> transducer. The ARS has demonstrated a high reliability of the solenoid valves under extreme climatic variations and conditions; and

- The double bubbler utilizes a two-stage regulator/flow control system to maintain a relatively constant bubble-feed rate that is independent of temperature and rapids rises in stream stage.

As a result of the physical configuration and operation of the double-bubbler system to be installed a RMA, the previously-described sources of error inherent in the standard bubbler gage are eliminated in the double-bubbler system.

Comment 12: Please provide a table summarizing both the type of permanent control structure (flume, weir, etc.) located at each of the surface water quantity gaging stations and the maximum/minimum capacity of the structure.

Response: A table and discussion of the type of permanent control structures at each gaging station will be provided in the First Year Surface Water Annual Report. Information on the Maximum/ minimum capacity of these structures will be provide if available.

Comment 13: The SWCMP states on page 48 that lake storage volume information will be retained by the Army and provided on an as needed basis. The State requests copies of all collected and analyzed data in the lake stage-measurement segment of the SWCMP, including the monthly water budget and storage volume of each lake.

Response: Lake stage/volume and stage/area relationships are provided in the Water Remedial Investigation Report (Ebasco, 1989). Lake volume and water balance calculations are provided for the period of October 1985 to September, 1987 in this document. The Army does file this information with the State Engineer's Office on an annual basis.

Table 1 Additional First Creek Chemical Sampling Locations and Rationale

Station No.	Comments
SW08-001	necessary to verify previous ESE (1988) results that this sampling point is just upgradient of a gaining section of the stream
SW05-001	old First Creek water quality monitoring station maintains historical data base
SW31-002	indicates contaminant contribution from Upper Derby Lake Overflow important with respect to potential Eastern Upper Derby Lake discharges during storm events and high-flow routing through the Uvalda Interceptor
SW31-001	historical contamination - indicates influence of Toxic Storage Yard runoff on First Creek
SW30-002	indicates influence of North Plants runoff on First Creek (assumes monitoring station is located downstream from confluence of tributary and First Creek)
SW24-001	historical contamination - indicates contaminant contribution from Sewage Treatment Plant effluent on First Creek
SW24-004	indicates influence of Sewage Treatment Plant effluent on First Creek
SW24-003	indicates influence of North Bog discharge on First Creek

Part III: Comments of and Responses to MKE/Shell Oil Company

RESPONSES TO
MKE/SHELL COMMENTS
ON THE COMPREHENSIVE MONITORING PROGRAM
DRAFT FINAL TECHNICAL PLAN FOR SURFACE WATER
APRIL 1989

Comment 1: Page 22, second paragraph, first sentence;
The collection locations of these samples along First Creek should be stated.

Response: The historical surface-water collection locations on First Creek cited by ESE have been included in the text in Section 2.2.4. Identification of historical sampling locations on First Creek and other surface-water sampling sites on RMA will be provided in the First Year Surface Water Annual Report. A historical review of analytical data for the period of 1979 to 1987 will also be provided for these locations.

Comment 2: Page 26, fourth paragraph, first sentence;
How will the "uncoordinated movement" of surface water on RMA be eliminated?

Response: The text has been expanded to explain how the Surface Water Management Program will eliminate the uncoordinated movement of surface water on RMA.

Comment 3: Page 26, fourth paragraph, second sentence;
Would Upper Derby Lake be maintained at a low level to have the capability of detaining storm flows? Under what conditions would overflow be passed to First Creek? The effects of additional recharge from Upper Derby Lake to groundwater on the DBCP plume should be assessed.

Response: Water levels within the lakes system are regulated to meet storm runoff, facility, and wildlife needs. Inflow from off-post sources can be directed along several optional pathways depending on individual lake levels and flow conditions. Upper Derby Lake is utilized at times to accept storm flows. Under certain conditions flow from the Uvalda interceptor is routed into Upper Derby Lake. Depending on the water storage in Lower Derby Lake and Ladora Lake Storm flows from Highline Lateral can also be directed to Upper Derby Lake. The retention time for the water stored in Upper Derby Lake is variable. Overflow from Upper Derby Lake has not been passed to First Creek since before 1982. It is not anticipated that overflow from Upper Derby will be directed to First Creek in the near future.

Monitoring of any impact of additional recharge from Upper Derby Lake to ground water on the DBCP plane would be done by the Ground Water Element of the CMP.

Comment 4: Page 26, fourth paragraph, third sentence;
Are these flows "storm" flows? Would all flows be routed or just the overflow from Havana Pond? The impacts of increased infiltration of flows in the Irondale Gulch Basin on the DBCP plum should be assessed.

Response: The text has been changed to indicate that only certain storm flows would require water to be released from Havana Pond. Circumstances which warrant the release of water from Havana Pond are regulated by the Chief Facility Engineer at RMA. Monitoring of any impact caused by increased infiltration created by surface-water flows in the Irondale Gulch Basin on the DBCP Plume would be done by the Ground Water Element of the CMP.

Comment 5: Page 36, third paragraph, second sentence;
It is generally accepted methodology for stream water quality monitoring to sample on a quarterly or monthly basis to characterize seasonal trends. Obviously, this methodology would increase the costs of the surface water monitoring program. However, seasonal trends in water quality may not be detected or characterized quantitatively with only two samples per year.

Response: Sampling is conducted twice a year with consideration given to the hydrologic cycle and its influence on stream flow conditions. Spring sampling and storm sampling collect representative analytical data from flows occurring under high flow conditions. Fall samples are representative of low flow conditions.

Comment 6: Page 37, Table 3.3-1;
If, as stated in the technical plan, USATHAMA methods are going to be used for the laboratory analyses of these parameters EPA methods should not be listed here.

Response: Table 3.3-1 has been changed to indicate the USATHAMA methods to be used in the analysis of samples collected during the Surface Water CMP.

Comment 7: Page 49, second paragraph, last sentence;
Need reference for CMP Analytical Procedures Manual.

Response: The CMP Analytical Procedures Manual has been written and is presently going through editorial revisions. A complete reference for this document will be provided when it has been officially released for review.

Comment 8: Page 50, first paragraph, fifth sentence;
What are the approved EPA methods for handling water samples containing suspended sediments?

Response: The text has been changed to indicate the approved EPA method used for analyzing water samples containing suspended sediments. Suspended sediments will be analyzed as total suspended solids which are determined by EPA Method 160.2 for non-filterable residue.

Comment 9: Page 52, third bullet;
Which First Creek stations. Why not present annual hydrographs at other stations, such as inflows to the lakes?

Response: The text has been updated to indicate that annual hydrographs of flow will be provided for all active monitoring stations.

Comment 10: Page 54, second paragraph, first sentence;
What types of statistical tests will be considered and used for data analysis? No mention is made of this methodology here or anywhere else in the plan, yet the selection and use of appropriate statistical procedures is critical to the correct interpretation of data and derivation of conclusions and recommendations.

Response: The text has been expanded to indicate the type of statistical analyses to be performed on the surface-water quality database.

Comment 11: Page 56, first paragraph, last sentence;
Need reference for the Quality Assurance/Quality Control Plan for the CMP.

Response: The Quality Assurance/Quality Control Plan for the CMP has been written and is presently going through editorial revisions. A complete reference for this document will be provided when it has been officially released for review.

Comment 12: Page 61, first paragraph, first sentence;
Need reference for the Health and Safety Plan for the CMP.

Response: The Health and Safety Plan for the CMP has been written and is presently going through editorial revisions. A complete reference for this document will be provided when it has been officially released for review.

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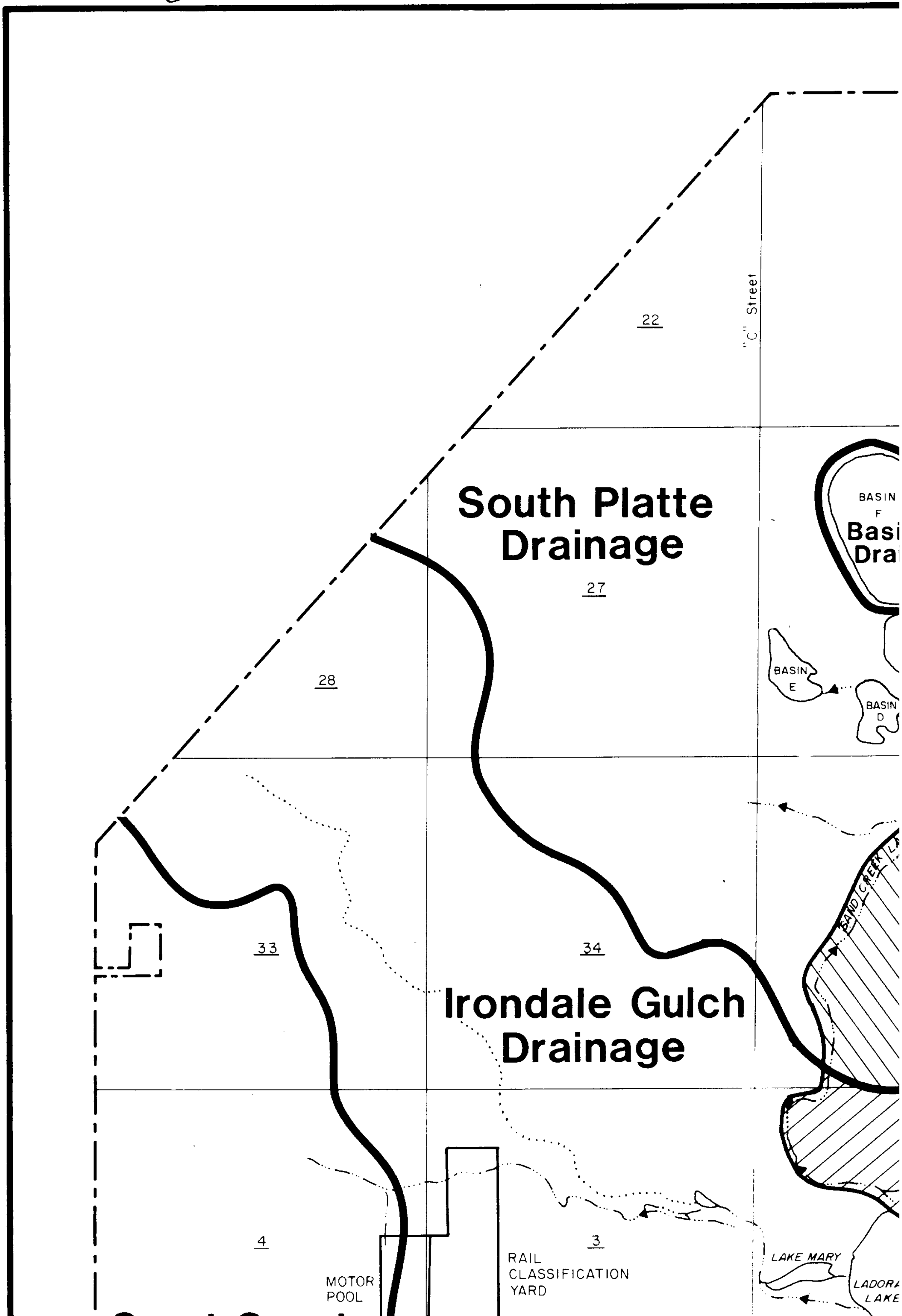
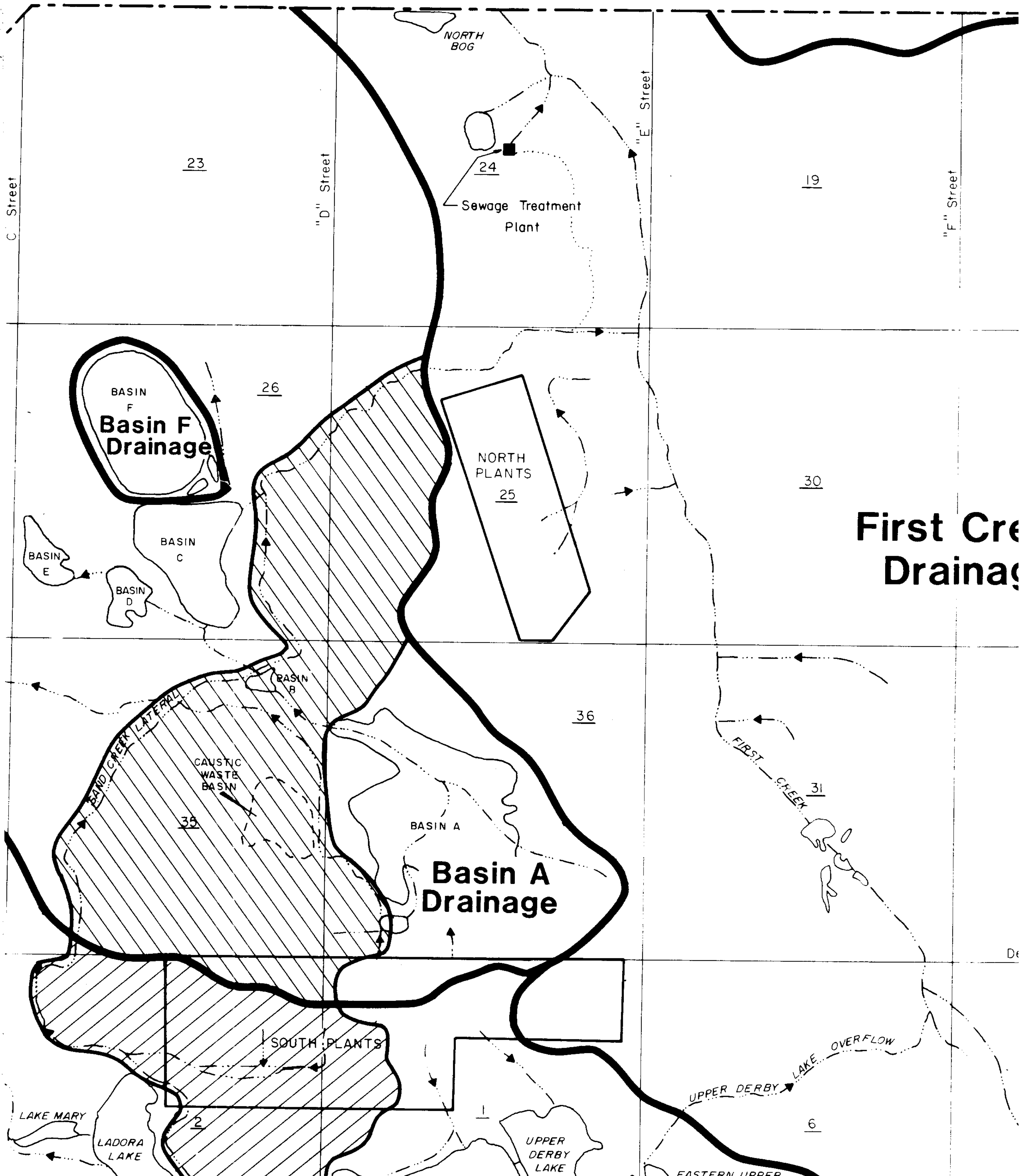
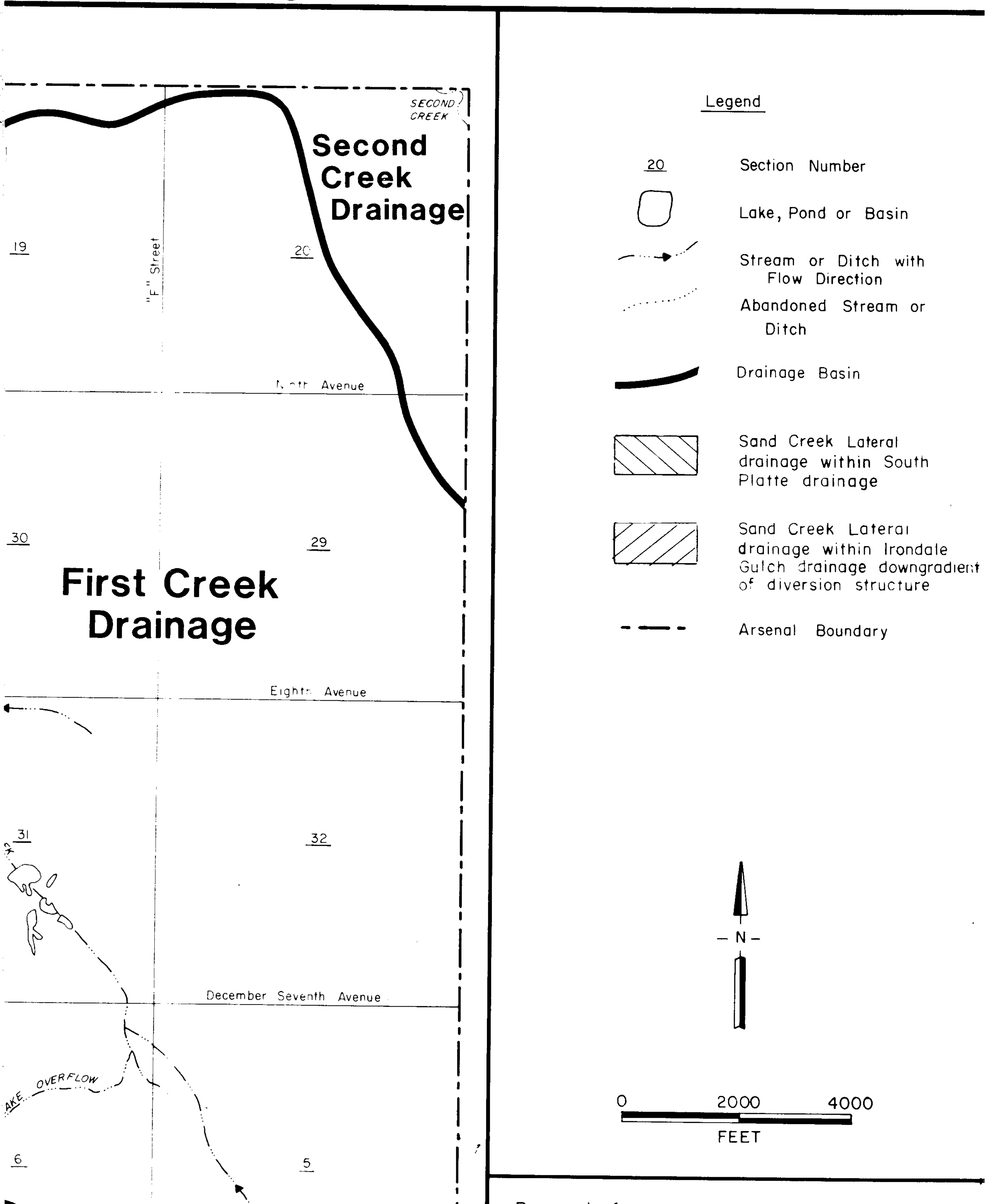

"C" Street
22
South Platte
Drainage
27
28
BASIN
F
Basi
Drai
BASIN
E
BASIN
D
SAND CREEK
33
34
Irondale Gulch
Drainage
4
3
MOTOR
POOL
RAIL
CLASSIFICATION
YARD
LAKE MARY
LADOR
LAKE

②


NORTH BOG
23
24
19
"C" Street
"D" Street
"E" Street
"F" Street
Sewage Treatment Plant
26
BASIN F
Basin F Drainage
NORTH PLANTS
25
30
First Cre
Drainag
BASIN C
BASIN E
BASIN D
BASIN B
36
SAND CREEK LATERAL
CAUSTIC WASTE BASIN
35
BASIN A
Basin A Drainage
FIRST CREEK
31
De
SOUTH PLANTS
UPPER DERBY LAKE OVERFLOW
LAKE MARY
LADORA LAKE
2
1
UPPER DERBY LAKE
6
EASTERN UPPER

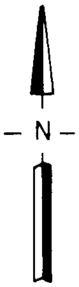
③


SECOND CREEK
Second Creek Drainage
19
"F" Street
20
North Avenue
30
29
First Creek Drainage
Eighth Avenue
31
32
December Seventh Avenue
LAKE OVERFLOW
6
5
Legend
20 Section Number
Lake, Pond or Basin
Stream or Ditch with Flow Direction
Abandoned Stream or Ditch
Drainage Basin
Sand Creek Lateral drainage within South Platte drainage
Sand Creek Lateral drainage within Irondale Gulch drainage downgradient of diversion structure
Arsenal Boundary
N
0
2000
4000
FEET

④

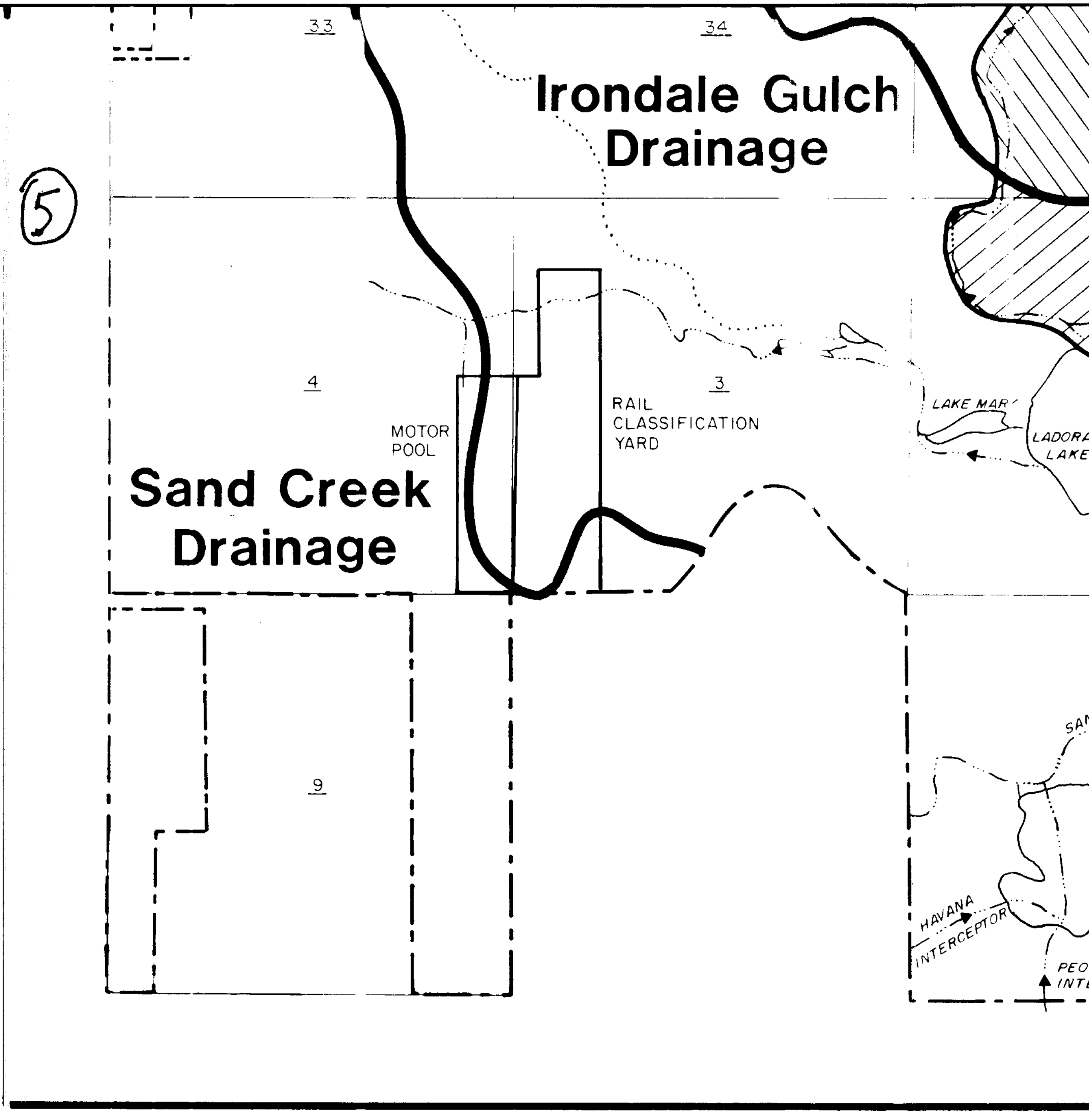
Legend

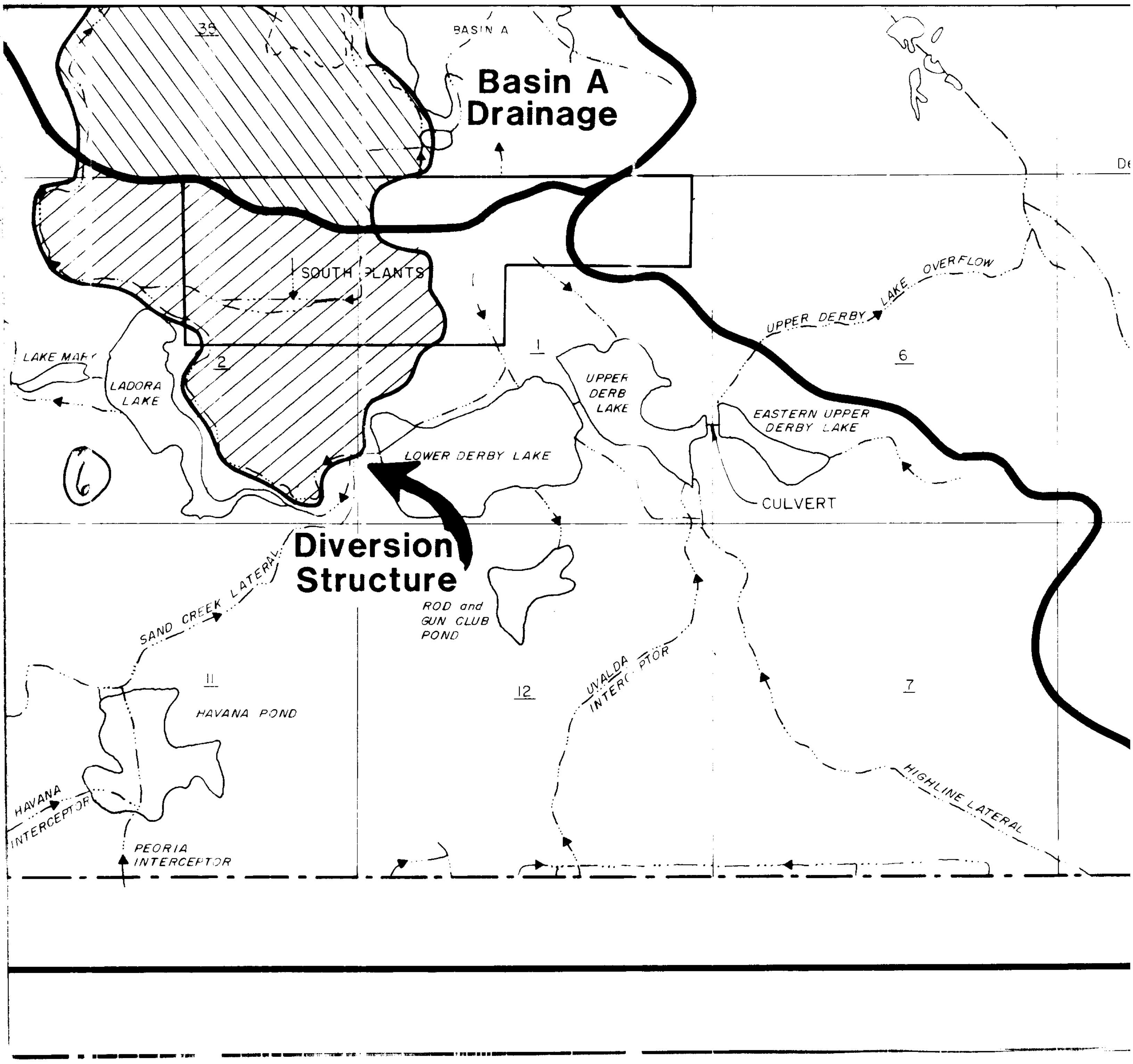
20	Section Number
▢	Lake, Pond or Basin
→	Stream or Ditch with Flow Direction
⋯	Abandoned Stream or Ditch
━	Drainage Basin
▧	Sand Creek Lateral drainage within South Platte drainage
▨	Sand Creek Lateral drainage within Irondale Gulch drainage downgradient of diversion structure
━ ━ ━	Arsenal Boundary

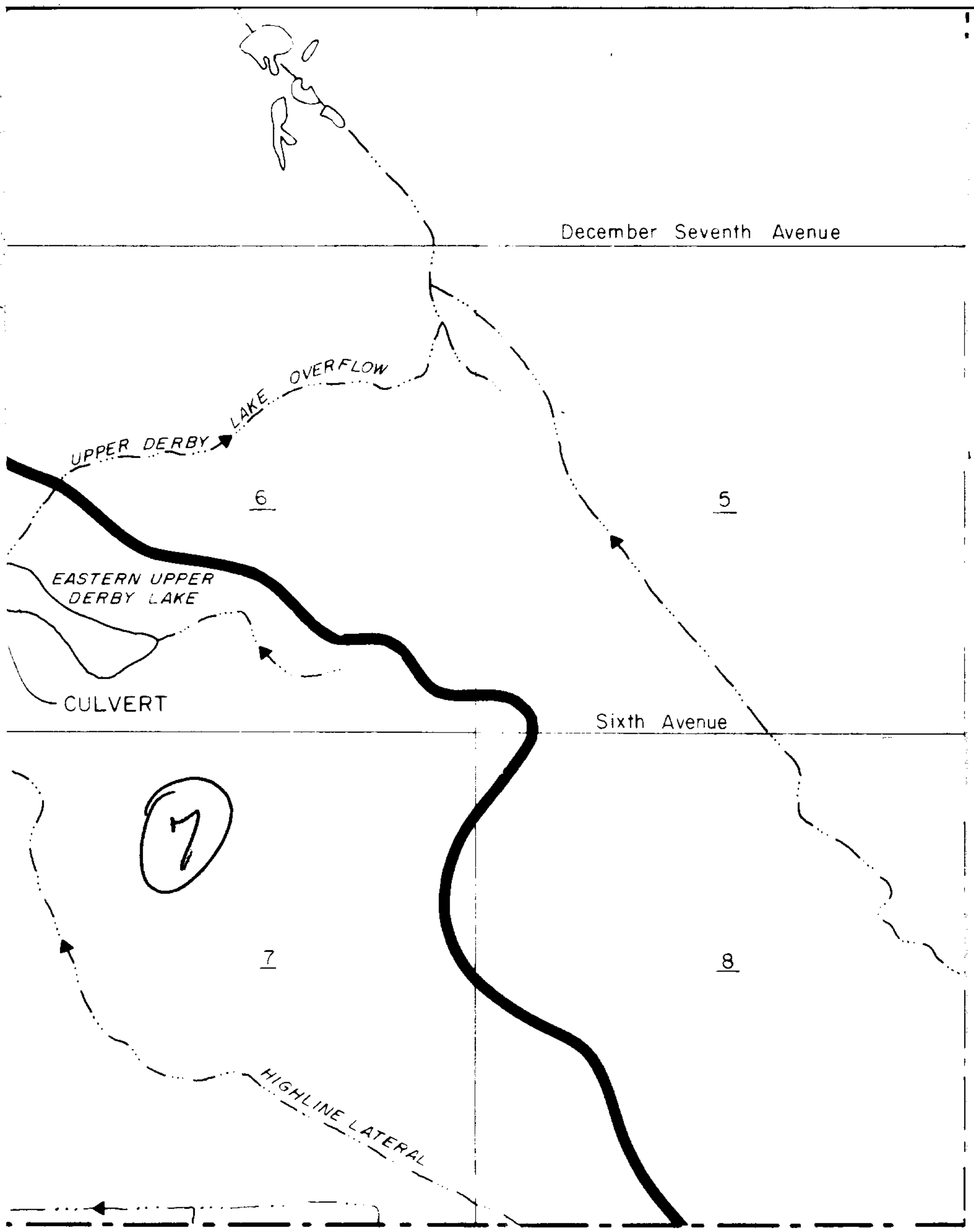


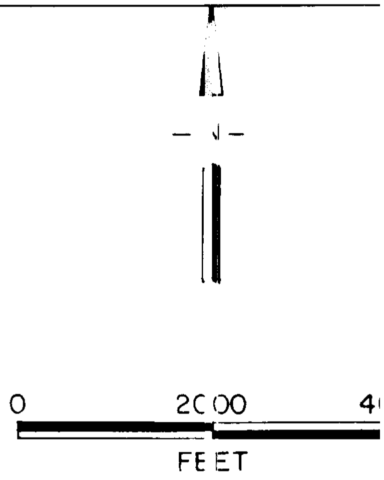
Prepared for :

⑤


33
34
Irondale Gulch Drainage
4
MOTOR POOL
RAIL CLASSIFICATION YARD
3
LAKE MAR
LADORA
LAKE
Sand Creek Drainage
9
SA
HAVANA INTERCEPTOR
PEO
INT


35
BASIN A
Basin A Drainage
De
SOUTH PLANTS
LAKE MARY
LADORA LAKE
2
6
1
UPPER DERBY LAKE
UPPER DERBY LAKE OVERFLOW
6
EASTERN UPPER DERBY LAKE
LOWER DERBY LAKE
CULVERT
Diversion Structure
SAND CREEK LATERAL
ROD and GUN CLUB POND
11
HAVANA POND
12
UVALDA INTERCEPTOR
7
HIGHLINE LATERAL
HAVANA INTERCEPTOR
PEORIA INTERCEPTOR





Prepared for:

U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

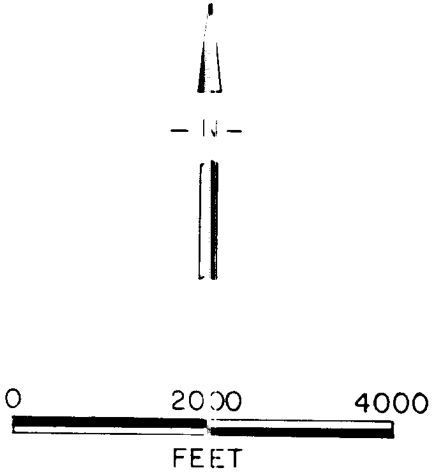
Prepared by:

R.L. Stollar & Associates, Inc.

Plate 2.1-1

Schematic Diagram of RMA Surface Water Features

CMP Surface Water Technical Plan
Prepared by: R.L. Stollar and Associat



Prepared for:

U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

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Prepared by:

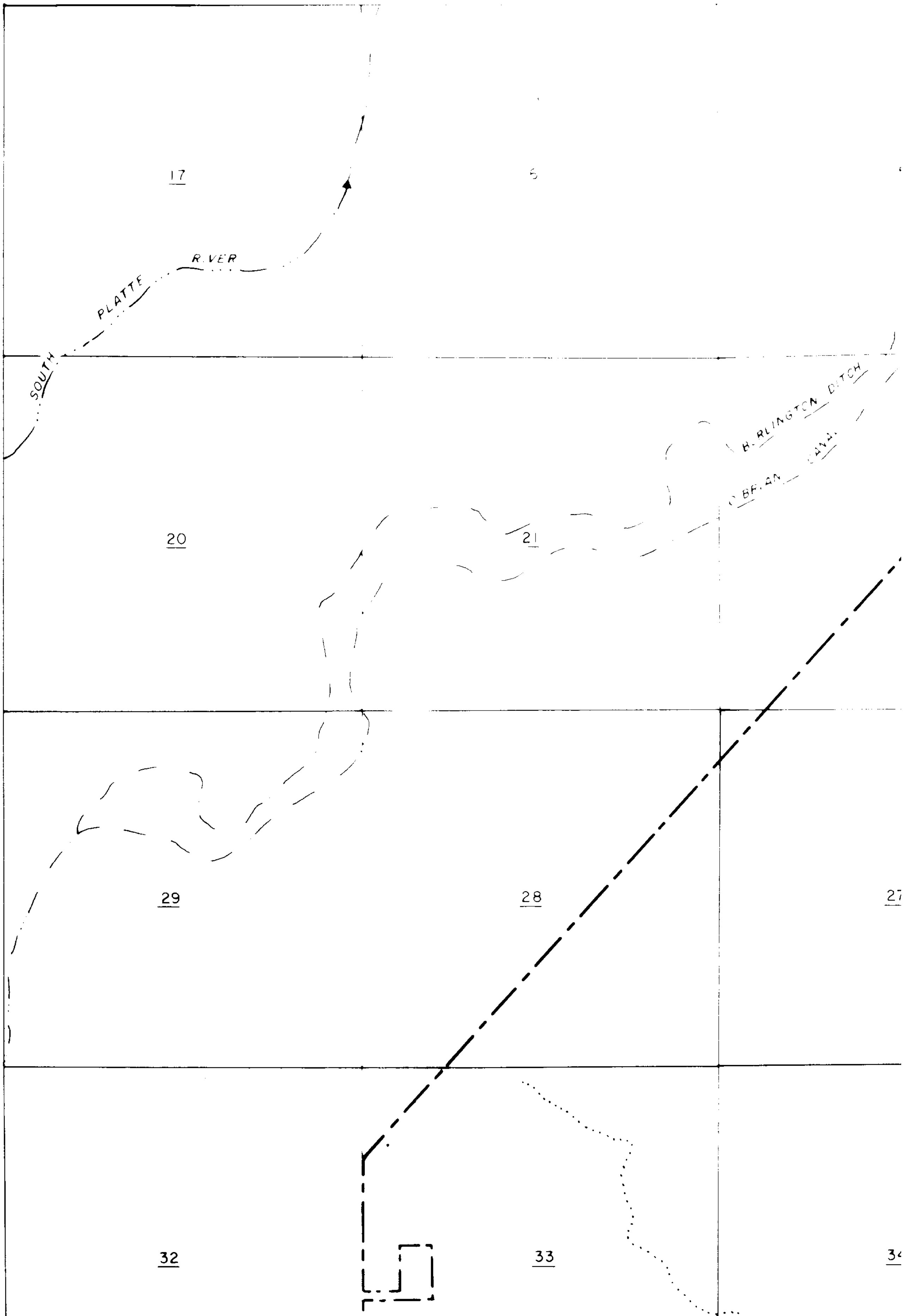
R.L. Stollar & Associates, Inc.

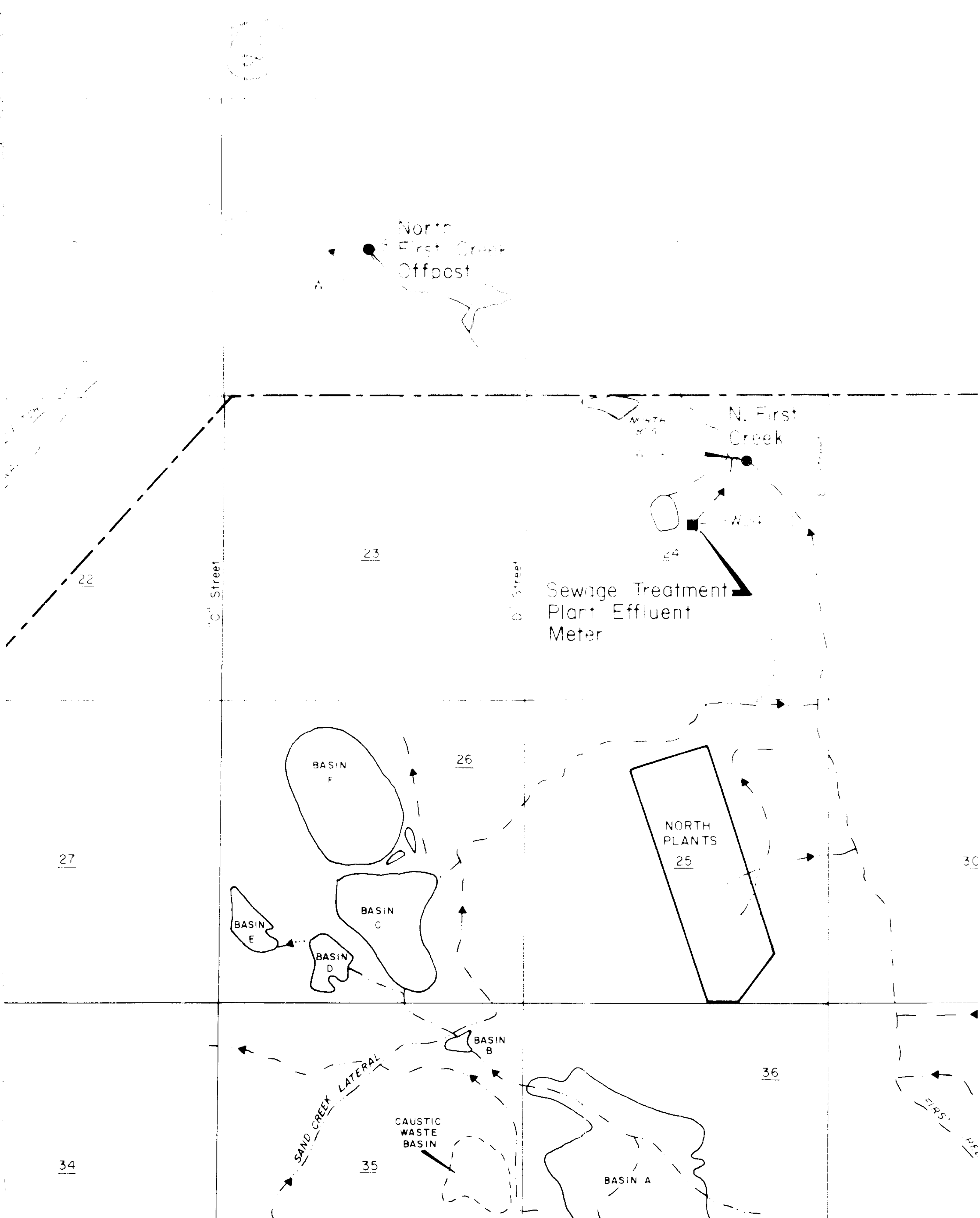
Plate 2.1-1

Schematic Diagram of RMA Surface Water Features

CMP Surface Water Technical Plan
Prepared by: R.L. Stollar and Associates

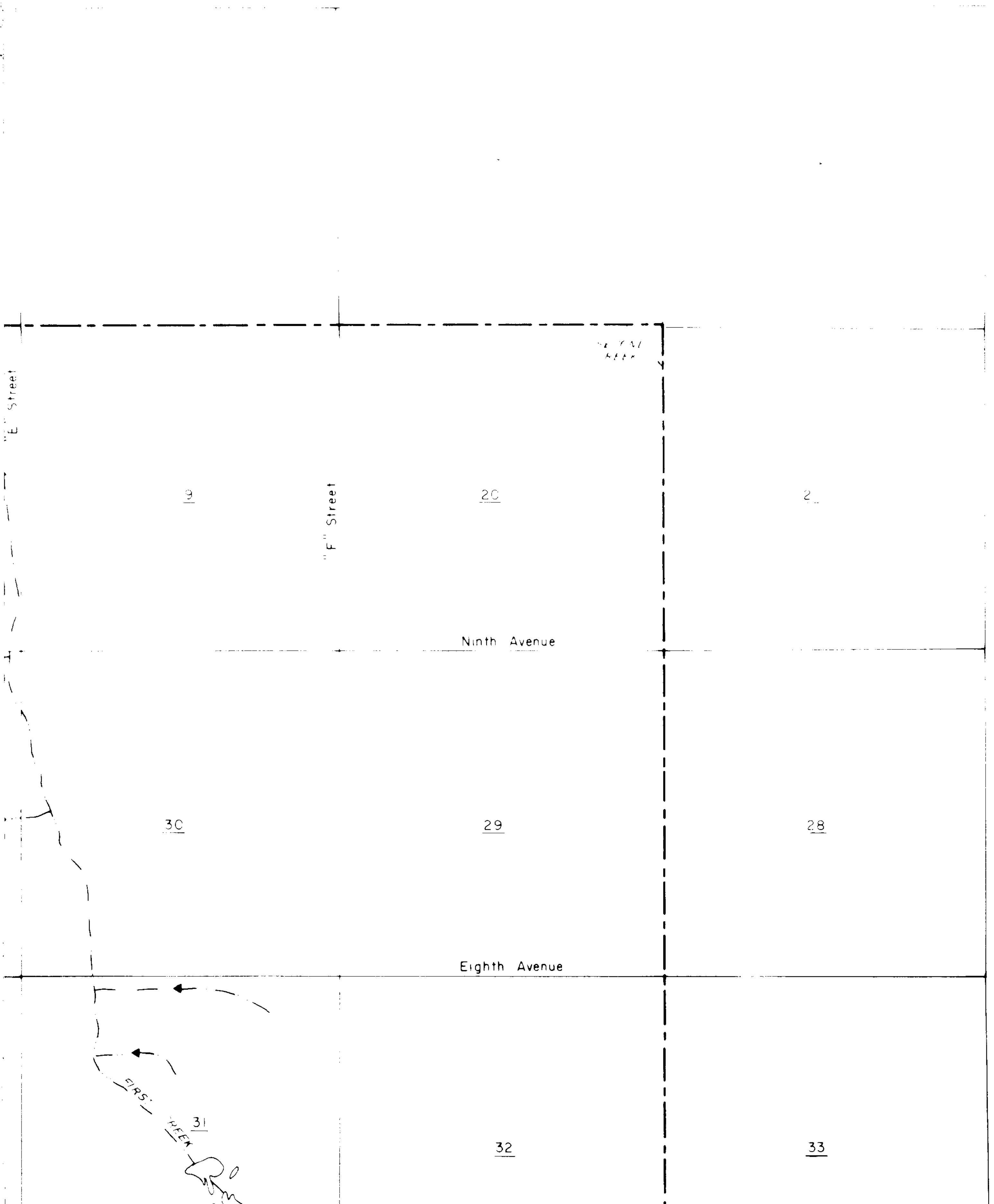
①


17
5
SOUTH PLATTE RIVER
BURLINGTON DITCH
O'BRIAN CANAL
20
21
29
28
27
32
33
34

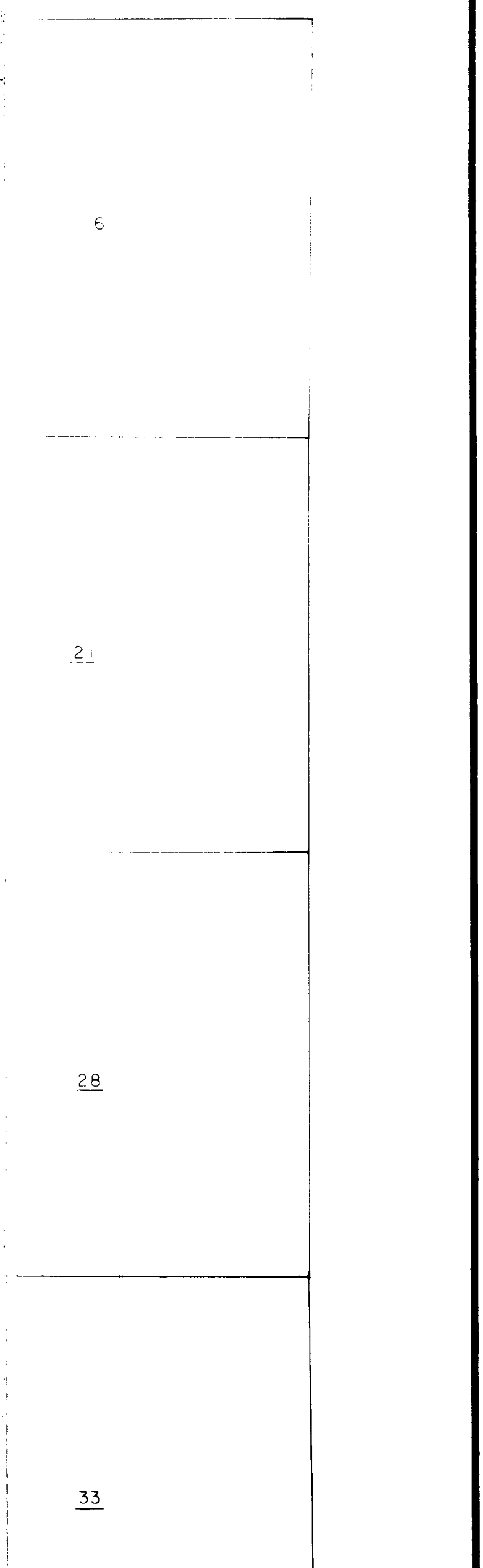


North
First Creek
Offpost
N. First
Creek
Sewage Treatment
Plant Effluent
Meter
22
23
24
C Street
D Street
26
27
BASIN
F
BASIN
C
BASIN
E
BASIN
D
NORTH
PLANTS
25
30
BASIN
B
36
SAND CREEK LATERAL
CAUSTIC
WASTE
BASIN
34
35
BASIN A

③


"E" Street
"F" Street
9
20
2
Ninth Avenue
30
29
28
Eighth Avenue
FIRST CREEK
31
32
33

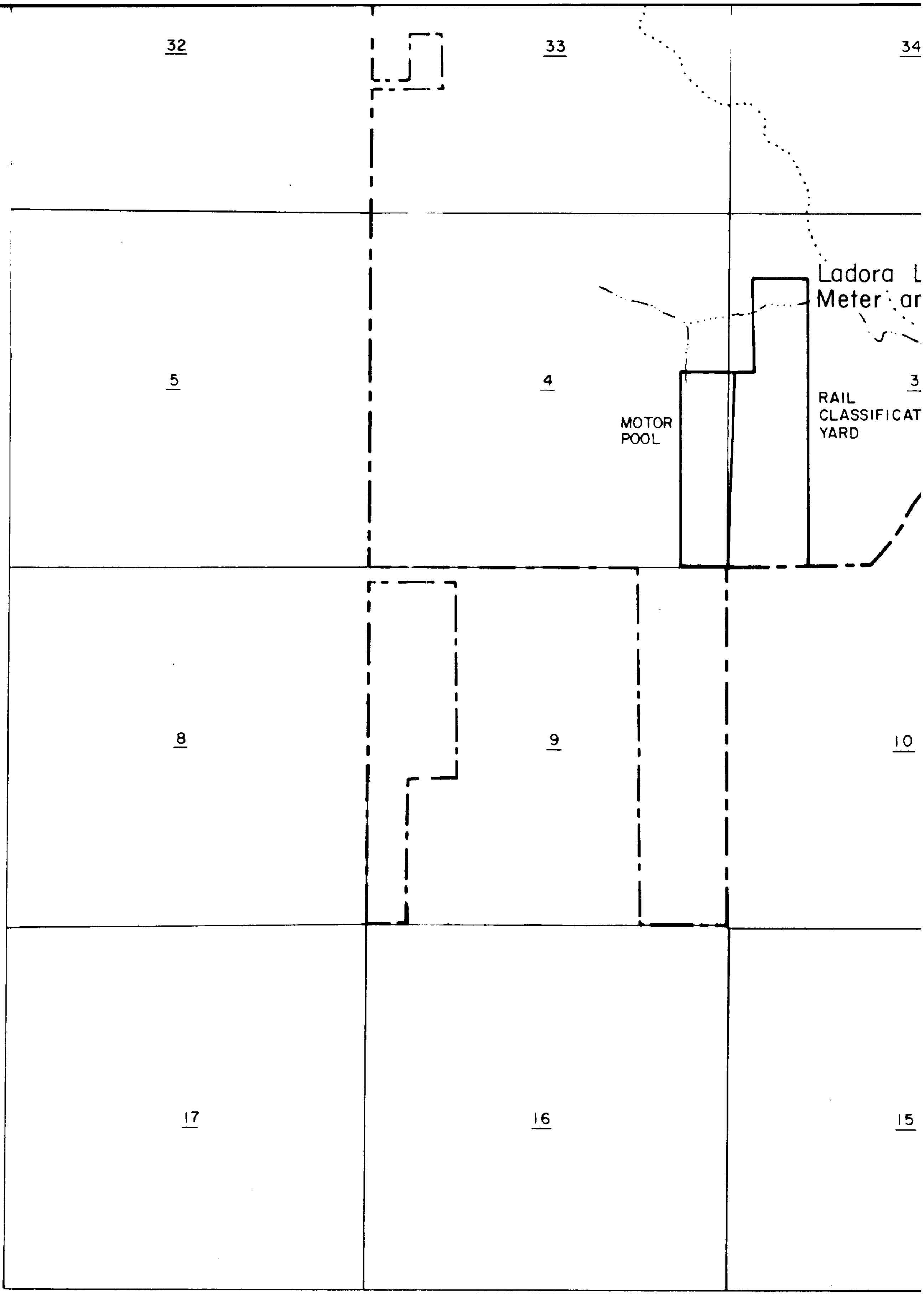
④



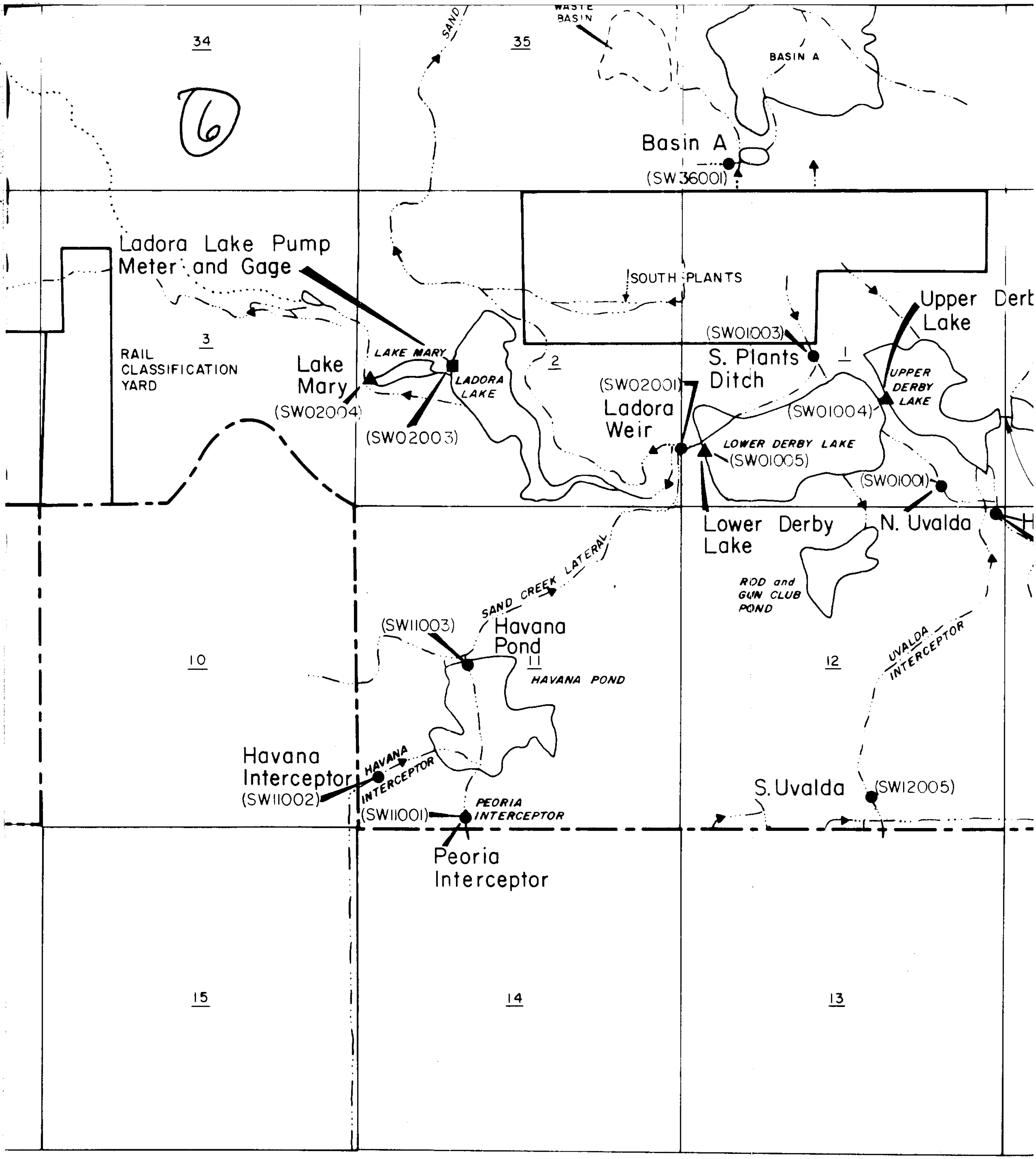
Legend

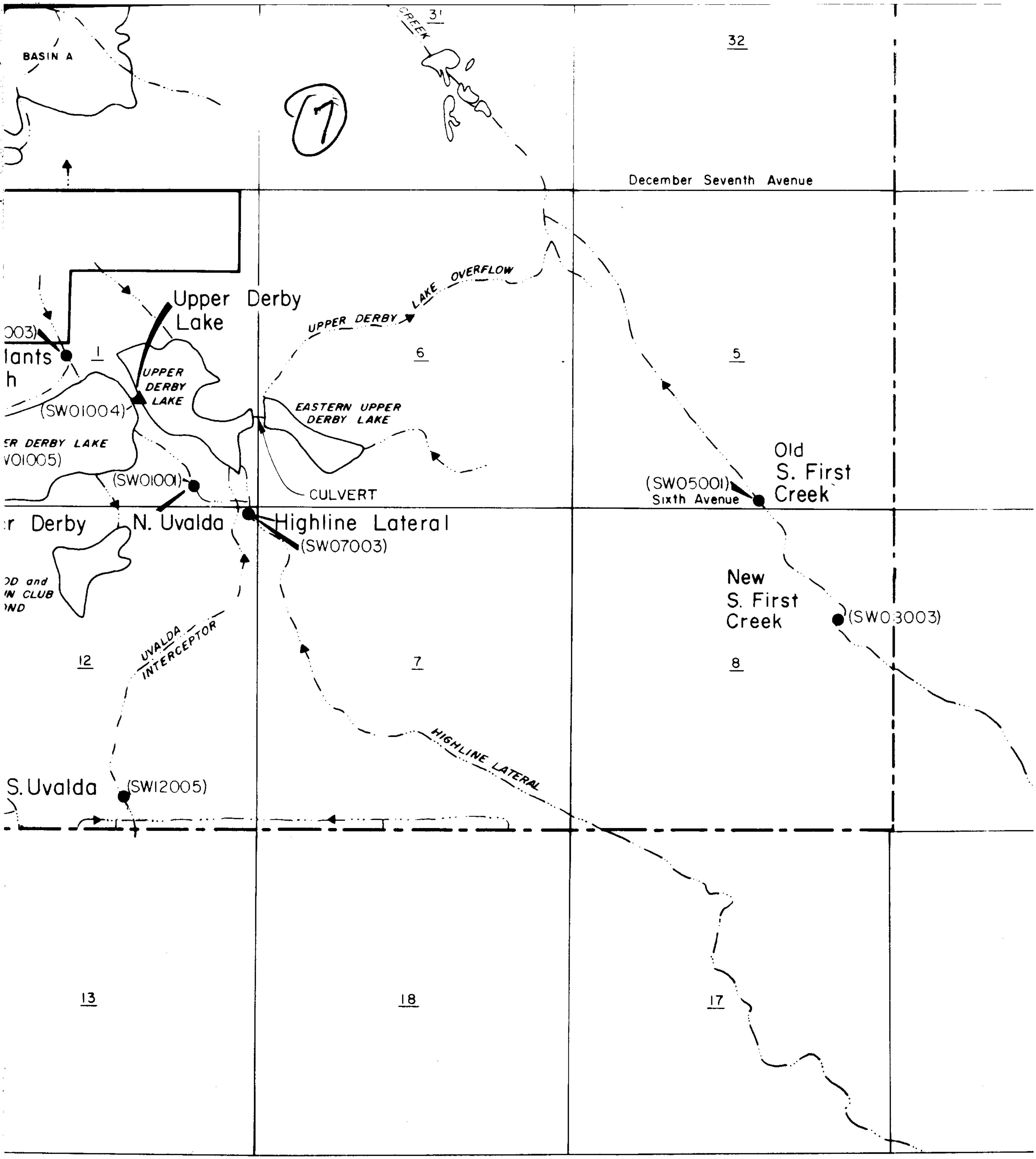
20	Section Number
◯	Lake, Pond or Basin
→	Stream or Ditch with Flow Direction
⋯	Abandoned Stream or Ditch
●	Water Level Recording Station Locations (SW37001) Corresponding Sampling Identification Number
▲	Staff Gage Locations
■	Flow Meter Locations
– — –	Arsenal Boundary

⑤


32
33
34
Ladora L
Meter ar
5
4
3
MOTOR
POOL
RAIL
CLASSIFICAT
YARD
8
9
10
17
16
15

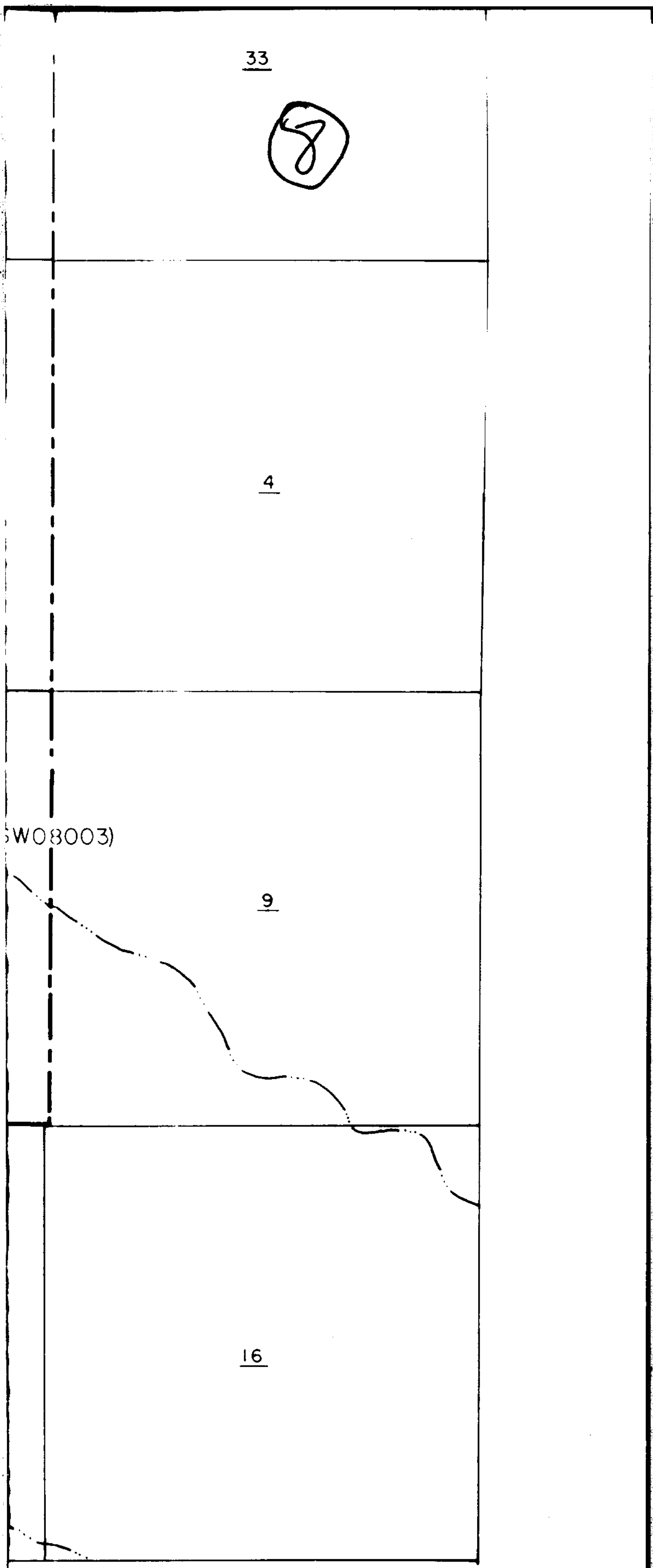
⑥

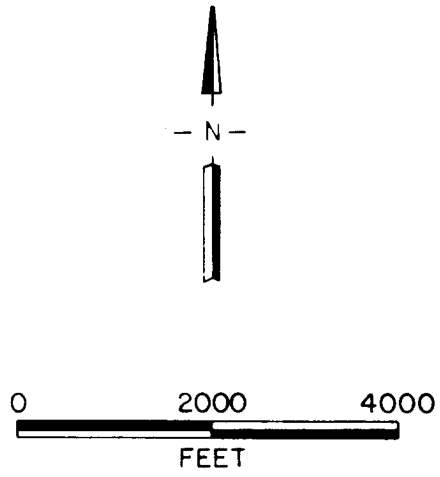

34
35
SAND
WASTE BASIN
BASIN A
Basin A
(SW36001)
Ladora Lake Pump Meter and Gage
SOUTH PLANTS
Upper Derb
Lake
(SW01003)
S. Plants Ditch
1
UPPER DERBY LAKE
3
RAIL CLASSIFICATION YARD
LAKE MARY
Lake Mary
(SW02004)
LADORA LAKE
(SW02003)
2
(SW02001)
Ladora Weir
(SW01004)
LOWER DERBY LAKE
(SW01005)
(SW01001)
Lower Derby Lake
N. Uvalda
H
ROD and GUN CLUB POND
SAND CREEK LATERAL
(SW11003)
Havana Pond
11
HAVANA POND
10
12
UVALDA INTERCEPTOR
Havana Interceptor
(SW11002)
HAVANA INTERCEPTOR
S. Uvalda
(SW12005)
(SW11001)
PEORIA INTERCEPTOR
Peoria Interceptor
15
14
13



⑦
BASIN A
31
CREEK
32
December Seventh Avenue
Upper Derby Lake
003)
lants
h
1
UPPER DERBY LAKE
(SW01004)
ER DERBY LAKE
V01005)
(SW01001)
N. Uvalda
r Derby
Highline Lateral
(SW07003)
UPPER DERBY LAKE OVERFLOW
6
EASTERN UPPER DERBY LAKE
CULVERT
5
Old S. First Creek
(SW05001)
Sixth Avenue
New S. First Creek
(SW03003)
OD and
N CLUB
ND
UVALDA INTERCEPTOR
12
7
8
HIGHLINE LATERAL
S. Uvalda
(SW12005)
13
18
17

⑧





Prepared for:

U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

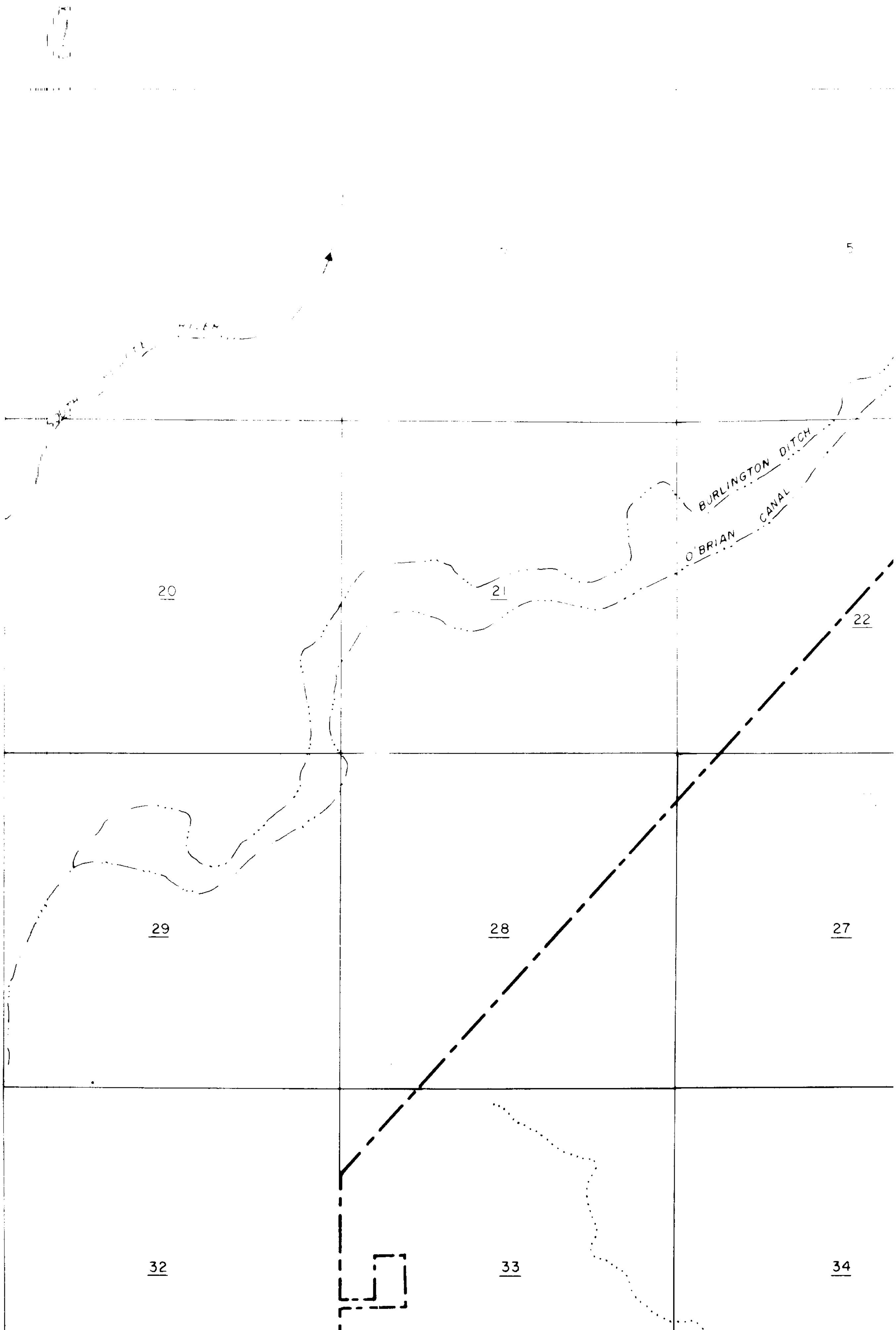
Prepared by:

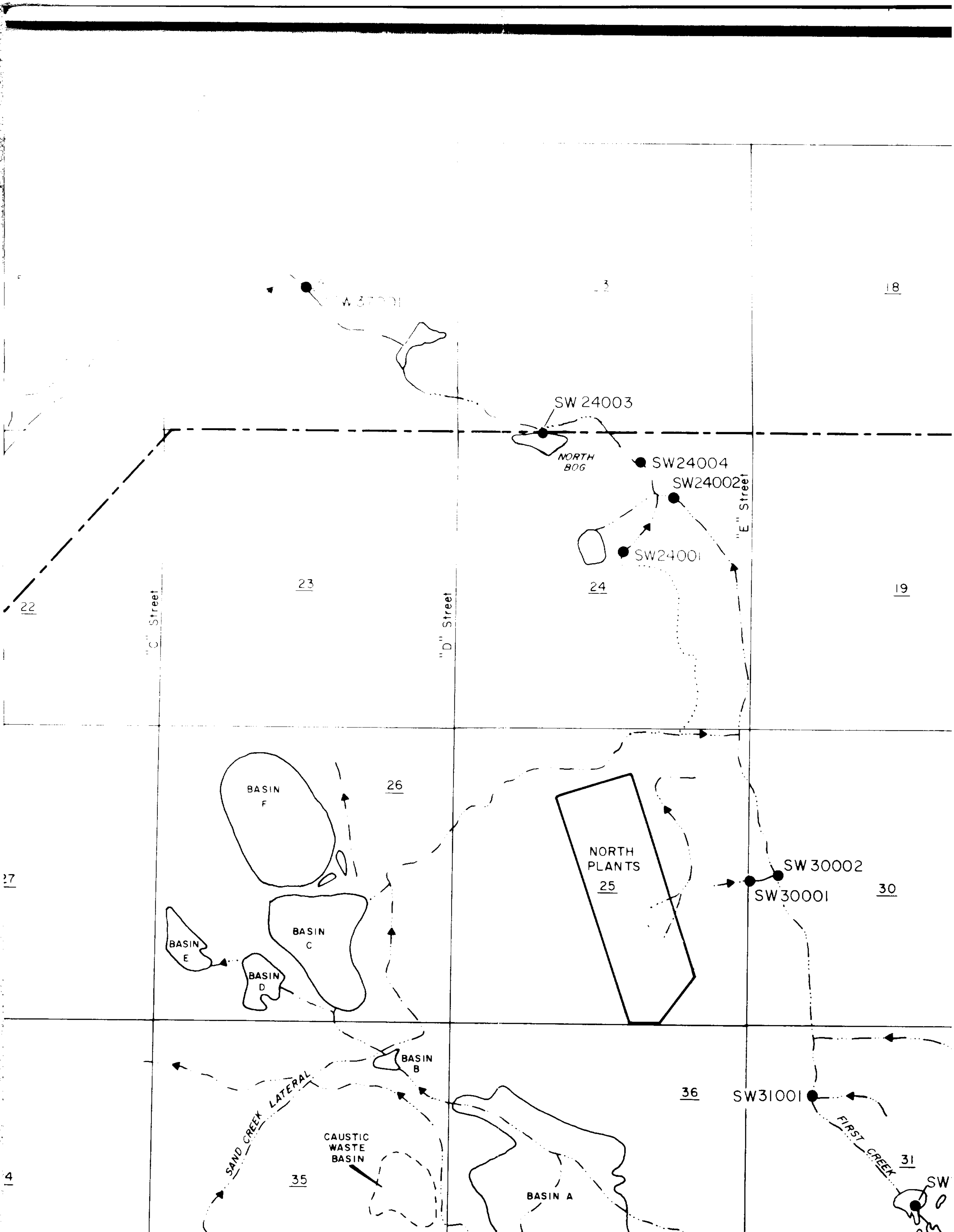
R.L. Stollar & Associates, Inc.
Harding Lawson Associates

Plate 2.2-1

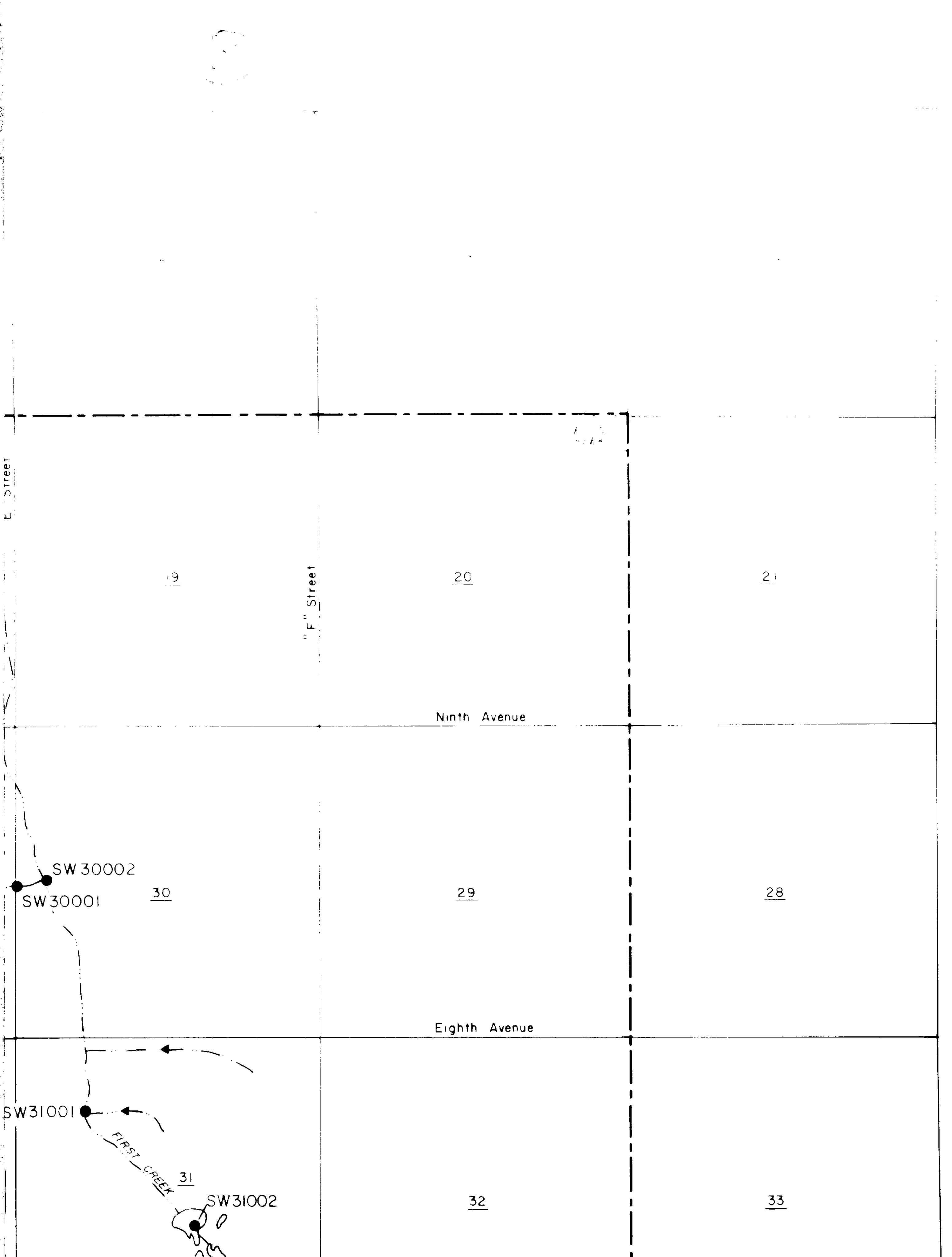
Surface Water Monitoring Station Locations

CMP Surface Water Technical Plan
Prepared by: R.L. Stollar and Associates

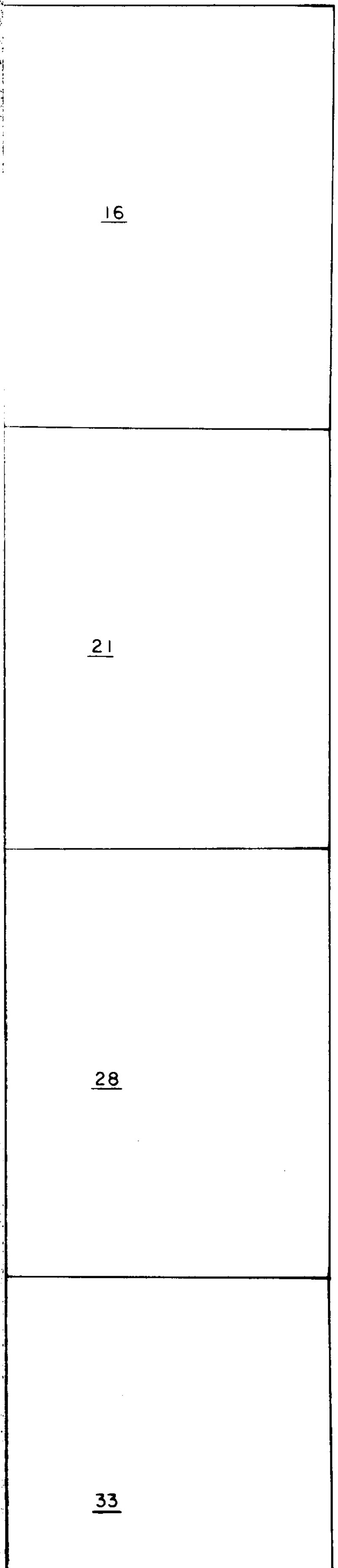

5
BURLINGTON DITCH
O'BRIAN CANAL
20
21
22
29
28
27
32
33
34



W 37001
3
18
SW 24003
NORTH BOG
SW24004
SW24002
"E" Street
SW24001
22
"C" Street
23
"D" Street
24
19
26
BASIN F
27
NORTH PLANTS
25
SW30002
SW30001
30
BASIN C
BASIN E
BASIN D
BASIN B
36
SW31001
SAND CREEK LATERAL
CAUSTIC WASTE BASIN
FIRST CREEK
31
4
35
BASIN A
SW


"E" Street
19
"F" Street
20
21
Ninth Avenue
SW30002
SW30001
30
29
28
Eighth Avenue
SW31001
FIRST CREEK
31
SW31002
32
33

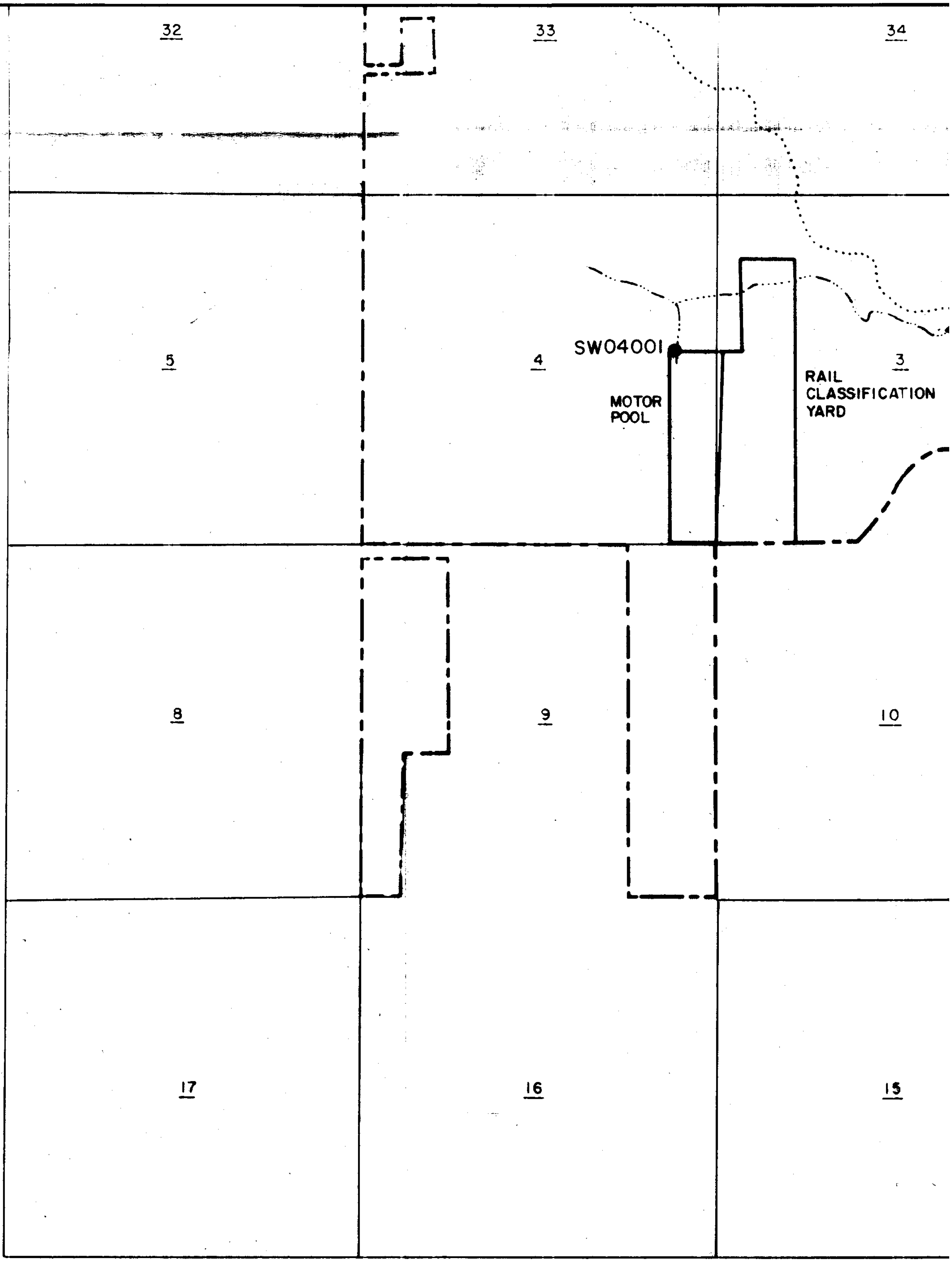
4

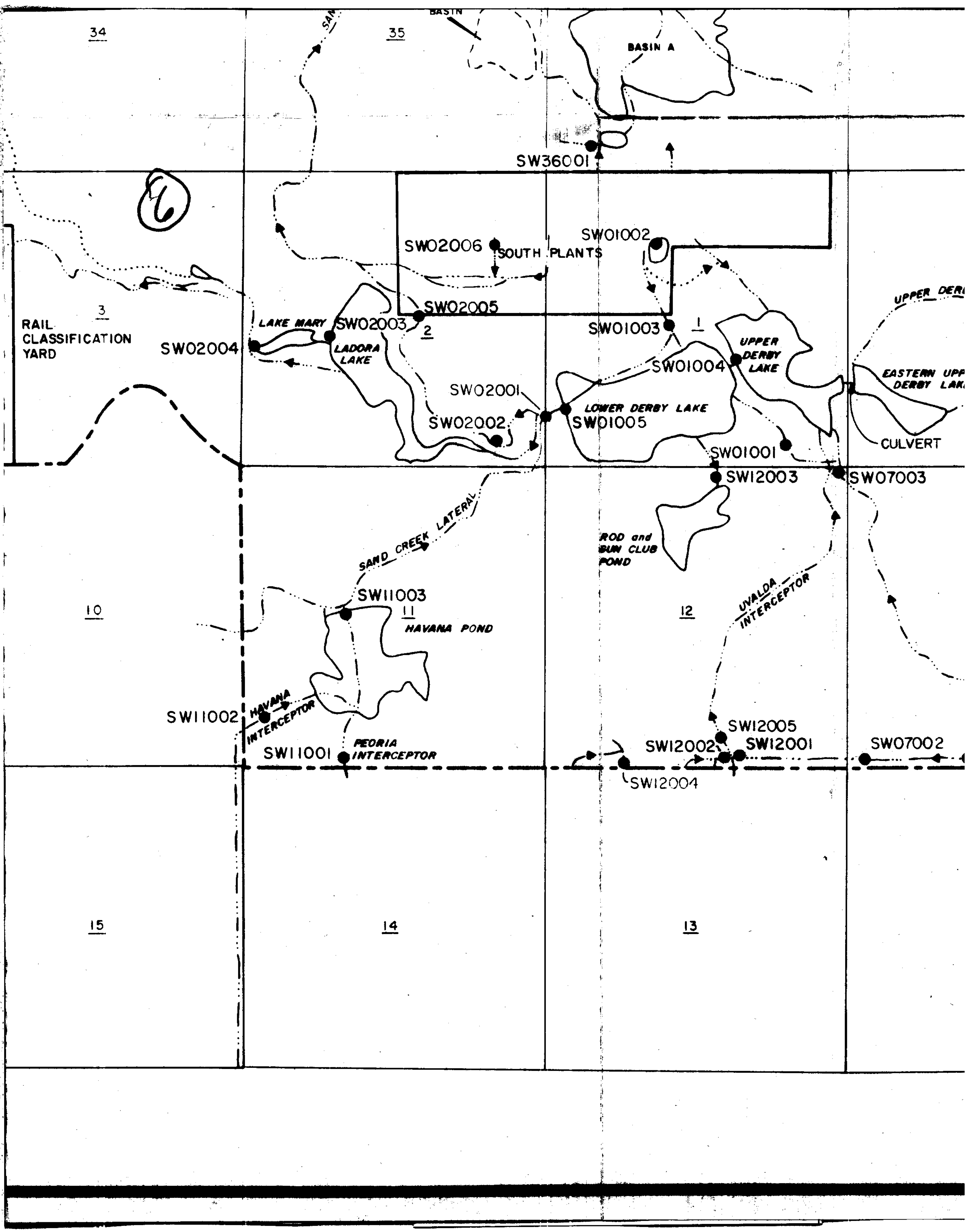


Legend

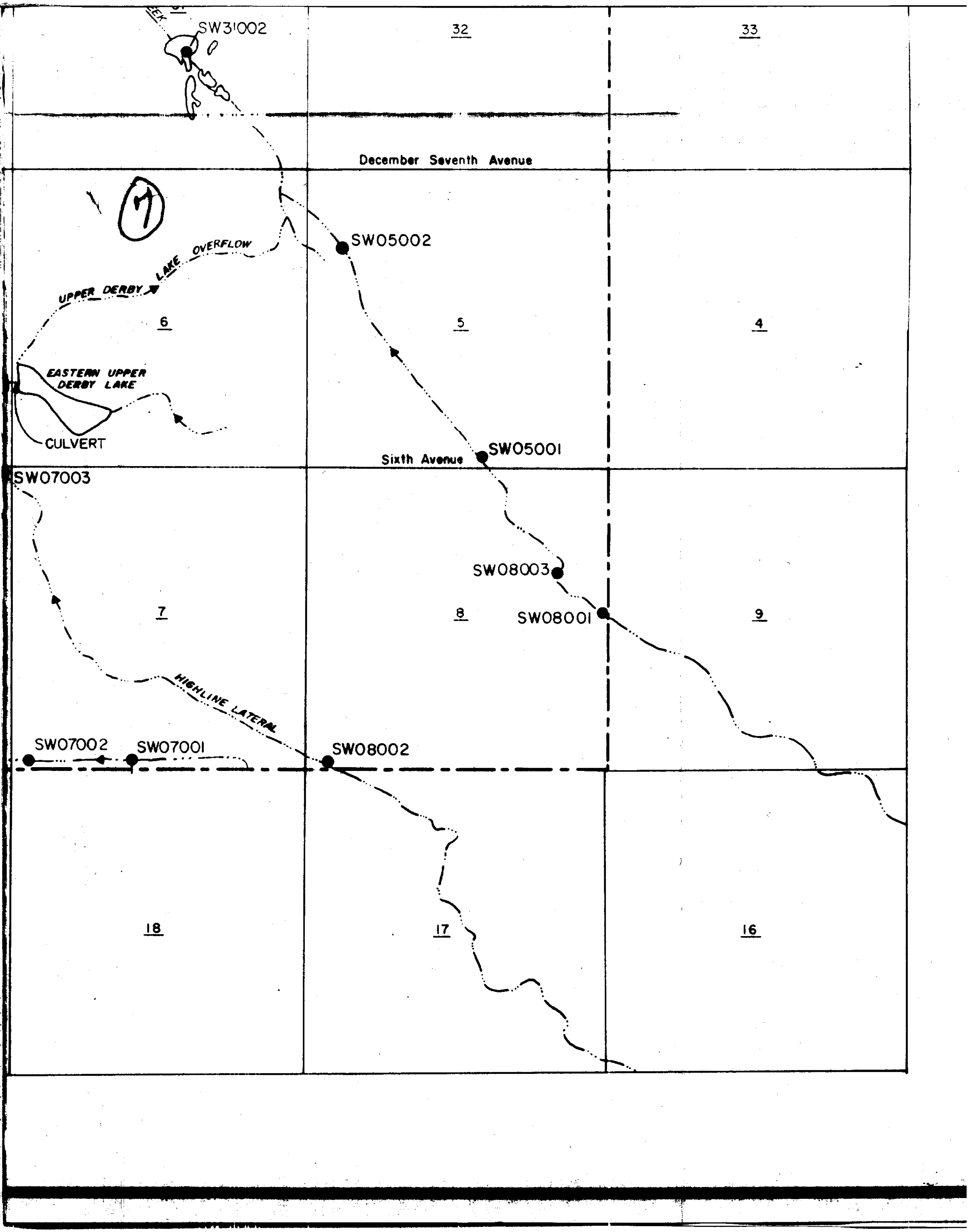
20	Section Number
◯	Lake, Pond or Basin
← · · · —	Stream or Ditch with Flow Direction
· · · · · ·	Abandoned Stream or Ditch
● SW24001	Surface Water Sample Location
— —— —	Arsenal Boundary

5

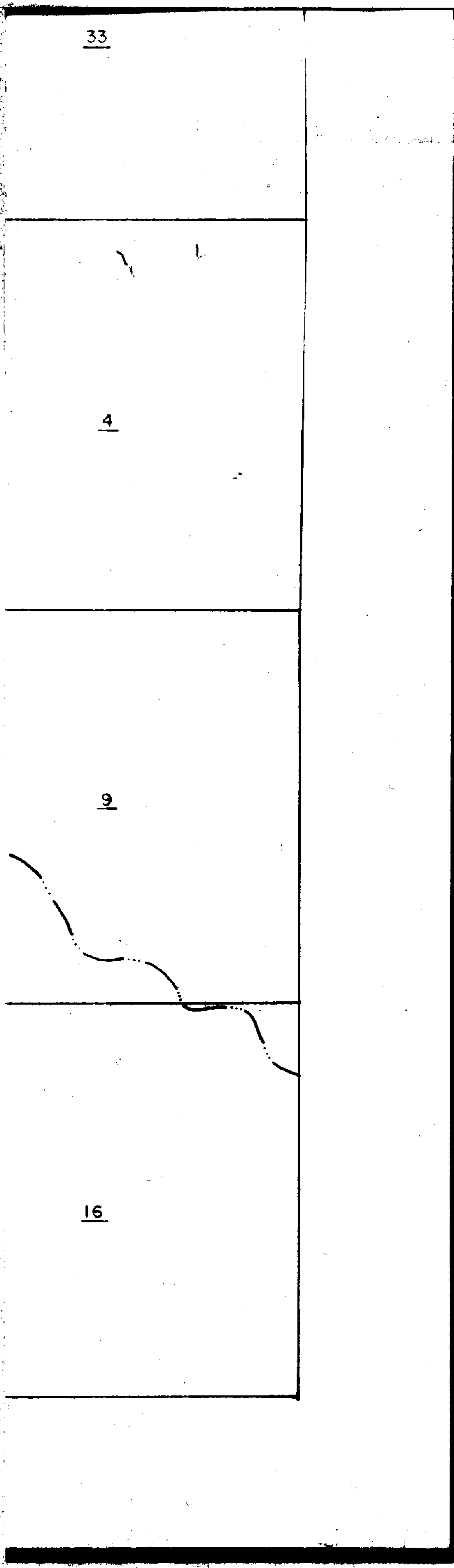

32
33
34
5
4
3
SW04001
MOTOR POOL
RAIL CLASSIFICATION YARD
8
9
10
17
16
15



34
35
BASIN
BASIN A
SW36001
⑥
SW02006
SOUTH PLANTS
SW01002
SW02005
UPPER DERB
3
RAIL CLASSIFICATION YARD
LAKE MARY
SW02003
2
SW01003
1
UPPER DERBY LAKE
SW02004
LADORA LAKE
SW01004
EASTERN UPP DERBY LAK
SW02001
LOWER DERBY LAKE
SW02002
SW01005
CULVERT
SW01001
SW12003
SW07003
SAND CREEK LATERAL
ROD and GUN CLUB POND
SW11003
10
11
HAVANA POND
12
UVALDA INTERCEPTOR
SW11002
HAVANA INTERCEPTOR
SW12005
SW12002
SW12001
SW07002
SW11001
PEORIA INTERCEPTOR
SW12004
15
14
13



EEK
SW31002
32
33
December Seventh Avenue
7
SW05002
UPPER DERBY LAKE OVERFLOW
6
5
4
EASTERN UPPER DERBY LAKE
CULVERT
SW05001
Sixth Avenue
SW07003
SW08003
SW08001
7
8
9
HIGHLINE LATERAL
SW07002
SW07001
SW08002
18
17
16



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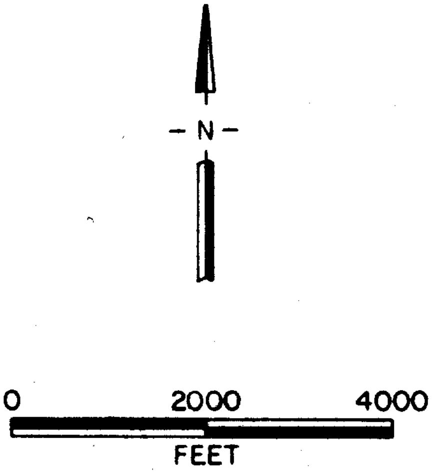

Prepared for:

U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.
Harding Lawson Associates

Plate 2.2-2

Surface Water Sampling Station Locations

CMP Surface Water Technical Plan
Prepared by: R.L. Stollar and Associates