Ready Mixed Concrete
Process Water
Best Management Practices Manual

December 2020

A manual developed by members of the California Construction & Industrial Materials Association (CalCIMA) in conjunction with the State Water Resources Control Board.

READY MIXED CONCRETE

PROCESS WATER
BEST MANAGEMENT PRACTICES MANUAL

CalCIMA

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A Publication of the California Construction and Industrial Materials Association
Environment and Natural Resources Committee

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TABLE OF CONTENTS

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1.0 INTRODUCTION

1.1 Scope and Purpose

Ready mix concrete batch facilities manufacture Portland cement concrete, a fundamental component of virtually every public- and private-sector construction project.

The manufacturing processes and supporting operational activities (collectively referred to as "operational activities") may affect surface water and ground water and, if not properly managed, the risk of impacting surface or groundwater increases. This manual of Best Management Practices is designed to provide guidance to the ready mix concrete industry in the State of California to mitigate that potential, thereby protecting the waters of the State from negative impacts to surface water and ground water from these operational activities.

This manual has been prepared by a consortium of producers operating in the State of California, with the cooperation of the State's lead water quality regulatory agency, the State Water Resources Control Board (SWRCB). The State's producers have been assisted in this effort by the California Construction and Industrial Materials Association (CalCIMA).

1.2 Overview

In the subsequent sections, this manual describes:

- **Operational Processes.** Ready mix concrete batch facilities manufacture ready mix concrete. The designs of these facilities vary widely and no two are identical; however, the processes used in manufacturing are similar from facility to facility. The purpose of this section is to provide an overview of operational processes, so that the potential for impacts to surface water and/or ground water can be better understood. This section is not prescriptive; it is descriptive; i.e., this is not a manual of operational practice. Additionally, the operational processes described do not apply to all facilities.

- **Best Water Management Practices.** These are practices which, when tailored to individual plant operations, properly designed and properly implemented, may mitigate the potential for negative impacts to surface water and/or ground water. These water management practices can be generally divided into three groups: 1) practices which involve the design of the facility, 2) practices which involve improvements to existing facility design, and 3) management practices which modify facility operations.

2.0 OPERATIONAL OVERVIEW

2.1 Ready Mix Concrete

All ready mix concrete batch facilities produce ready mix concrete, often referred to as Portland-cement concrete (so-called because Portland cement has historically been the primary cementitious material). Conceptually, the batching of ready mix concrete consists of the combining and mixing of prescribed amounts of cementitious material, aggregates (rock and/or sand), water, and possible admixtures.

- The cementitious materials used include but are not limited to Portland cement, flyash, silica fume and slag.
- The aggregates used include naturally occurring screened, washed, and sometimes crushed rock and/or sand.
- The water used is typically sourced from municipal supply or groundwater well. Process water generated during operational activities can be reintroduced to batch processes, as further described in subsequent sections.
- Admixtures used in the manufacture of ready mix concrete are widely variable and are described more fully later in this manual.

2.1.1 Central Mix Facilities vs. Transit Mix Facilities

A significant operational feature that divides ready mix facilities into two classes is the type of mixing employed. In a Central Mix facility, the concrete is mixed in plant-mounted equipment prior to being *dispensed* into a waiting ready-mix-concrete delivery truck (a.k.a.: ready mix truck). In a Transit Mix facility, the unmixed concrete components are placed directly into the ready mix truck and are mixed by the rotating drum of the truck on the way to the jobsite.

2.1.2 Ready Mix Concrete Batch Process Overview

A brief overview of the ready mix concrete batching process will facilitate an understanding of plant processes. Additional detail of batch processes will be presented in other areas of this manual.

- The Batch Process Concept
  - Batches of ready mix concrete are manufactured by weight – the weight of each individual raw material.
  - Some of each raw material (aggregates, cementitious materials, water, admixtures) must be "at-the-ready" to be introduced into its respective weighing process.

- The Batch Plant
  - The weighing and combining of the raw materials takes place in the batch plant.
  - The batch plant consists of:
    - Sufficient inventories of raw materials to manufacture at least one batch of ready mix concrete,
    - Weighing vessels,
    - The equipment necessary to move those raw materials into weighing vessels, and
    - The equipment necessary for moving the raw materials into and through the plant mixer (if the facility is a Central Mix facility) and into the ready mix truck.

- The Mix Design
  - The mix design is a "recipe" for the manufacture of a specific batch of ready mix concrete.
  - The mix design includes the weights of each raw material component required to produce the batch.

- Raw Material Inventory
  - As stated above, sufficient inventory of each raw material must be "at-the-ready" in the batch plant to be introduced into the batch process.
  - In many facilities, the capacity of "at-the-ready" inventory in the batch plant is insufficient to maintain extended production of ready mix concrete batches.
  - In most facilities, additional inventories of raw materials are maintained to feed the batch plant process.

- The Batch Process – In the Batch Plant
  - A customer requests a batch of ready mix concrete, to be manufactured according to a predetermined mix design.
  - The mix design drives a batch computer, which in turn drives various automated, sequential or simultaneous plant processes:
    - One or more aggregate materials will be dispensed into one or more weigh hoppers.
    - One or more cementitious materials will be dispensed into other weigh hopper(s).
    - Water will be weighed or metered.
    - Admixtures, if called for, will be similarly weighed or metered.

  - These raw materials will be combined, using conveyors, mechanical gates & valves, and other mechanisms, into:
    - The plant mixer drum (for a Central Mix facility), or
    - A waiting ready mix truck (for a Transit Mix facility).

- Delivery of Ready Mix Concrete
  - The mixed concrete is delivered to the customer.
  - Excess material not utilized by the customer typically returns to the facility – where it is resold or reused or reclaimed or disposed as described elsewhere in this manual.
  - The ready mix truck rinses the inside of the drum in preparation for the next batch of concrete to be delivered.

- Repeat
  - The process repeats, up to several hundred times per day.

- Time-Sensitive Nature of the Process
  - Fresh ready mix concrete is frequently described as "uncured" – meaning it is workable.
  - Most applicable standards require that uncured ready mix concrete be placed into its final disposition within 90 minutes of the time of manufacture.

2.2 Aggregates

The methods for handling aggregates at ready mix facilities vary widely. Aggregate sources and transportation, and methods for receiving, handling, and storage are presented below.

2.2.1 Aggregate Types

Aggregates used in the manufacture of ready mix concrete are usually coarse and fine aggregates that are generally described as follows:

- **Coarse Aggregates.** Coarse aggregates are generally defined as rock or gravel approximately one-quarter inch or larger. The aggregates are generally washed at the source (quarry, mine, etc.) and require little additional water at the plant except in the hottest regions, where water may be added (sprinklers) for moisture content and temperature management.
- **Fine Aggregates.** Fine aggregates are generally defined as rock or gravel particles less than one-quarter inch, a.k.a. "sand." Because of surface area, fine aggregates are typically received with higher water contents (by weight) than coarse aggregates. Additionally, fine aggregates may be sprinkled, either in stockpiles or while on conveyors during the handling process, for management of dust, and for production of quality ready mix concrete.
- **Non-Standard or Specialty Materials.** Most producers handle non-standard or specialty materials from time to time. These include screened glass particles, oyster shells, natural or manufactured low density aggregates (a.k.a. "lightweight" aggregates), and various products that are incorporated for architectural purposes.

2.2.2 Aggregate Transportation

The washed and graded aggregates are delivered to the ready mix facility using a variety of transportation modes:

- **Over-the-Road Trucking.** Over-the-road trucks deliver aggregates to the ready mix facility in bottom-dump trucks and end-dump trucks.
- **Rail.** Some ready mix facilities are equipped with rail spurs, in which case bottom-unloading rail cars may be used to deliver aggregates.
- **Barge/Ship.** Some ready mix facilities with frontage on navigable waterways receive aggregates by barge or ship. Unloading from the barge or ship typically utilizes buckets and/or conveyors that transfer the aggregates from barge or ship to shore.
- **Quarry-Fed Facilities.** Some ready mix facilities are co-located with a mine or quarry that produces aggregates. In these facilities, aggregates are transported to the ready mix facility using conveyors, over-the-road trucks, or off-road mine trucks.

2.2.3 Aggregate Receiving

The methods used for receiving aggregates at ready mix facilities vary widely, but several practices dominate:

- **Drive-Over Hopper.** Many ready mix facilities are equipped with a drive-over hopper, also referred to as a grizzly. An aggregate delivery vehicle (bottom-dump truck, end-dump truck, or uke) dumps the aggregate through the grizzly bar structure into the hopper. The hopper is fitted, at its base, with a clamshell gate. The aggregates pass through the gate onto a moving conveyor belt beneath the gate.

- **Windrowing and Loader Receiving.** Aggregates received by truck are, in some instances, placed directly on the ground. The aggregates may be dumped into a pile, if delivered by an end-dump truck. If delivered by a bottom-dump truck, a ribbon of aggregate is laid on the ground. A front-end loader then moves the aggregates, into some form of ground storage, into a hopper for conveyor-feed of a stockpile or overhead bin, or directly into an overhead bin.
- **Conveyor Receiving.** Facilities that are co-located with an aggregate mine or quarry and facilities that are equipped to receive materials by ship or barge often receive the materials by conveyor. The conveyor may place the material into some form of ground storage, into intermediate overhead storage, or into the overhead plant storage.

2.2.4 Aggregate Storage

Batch Plant Aggregate Inventory. A primary objective of aggregate receiving, handling, and storage at the ready mix facility is to maintain the quality and separation of the aggregates, so that they can be "at-the-ready" for individual weighing in the batch plant for the manufacture of ready mix concrete.
In most batch plants, the aggregates that are "at-the-ready" for introduction into the weighing process are located in bins or silos above the weigh hoppers.

Additional Aggregate Inventory. A second, but equally important objective of aggregate receiving, handling, and storage at the facility is to maintain sufficient inventories of materials within the facility, to maintain or replenish the supply of "at-the-ready" aggregates in the batch plant.
Ready mix concrete facilities maintain these additional aggregate inventories in any of several configurations:

- **Above-Ground Storage Bins.** Some ready mix facilities maintain inventories of aggregates in above-ground storage bins. These bins may be constructed of steel or concrete; a few, older facilities may exist where bins are constructed of wood. Aggregates are typically introduced to these bins by conveyor. Aggregates are typically removed from these bins by conveyor as well.
- **Ground Storage Bunkers or Stockpiles.** Some ready mix facilities maintain inventories of aggregates using ground storage. Ground storage may take the form of an unconfined stockpile, or it may be confined on two or three sides by a confining structure, such as a wall of concrete or a wall of large concrete blocks. Aggregates may be added to the stockpile or bunker by conveyor or by loader or by direct dump. Aggregates may be removed from the bunker or stockpile by loader or by an underground tunnel fitted with gates and conveyor(s).

2.2.5 Aggregate Handling

Plants use several practices to move the aggregates from the point or place at which they are received to their final disposition in the batch plant..

- **Conveyors.** Conveyors are used in some part of the ready mix batch process at virtually every facility. Conveyors are often utilized to move aggregates from the point of receipt to ground storage bunkers, ground storage stock piles, or overhead storage bins or silos. Conveyors are also often used to move aggregates from overhead bins or silos to other overhead bins or silos.

Conveyors located in tunnels beneath ground storage stockpiles can also be used to move aggregates from these stockpiles into overhead storage. Conveyors are also typically used to move aggregates from the aggregate weigh hopper(s) to the plant mixer or the ready mix truck. The number and arrangement of conveyors is highly plant-specific and variety of configurations is too great for discussion in this manual.

- **Loader-Fed.** Some ready mix facilities are designed so that overhead storage bins or conveyor-feed hoppers can be accessed (fed) by a front-end loader.
- **Bucket Conveyors.** Some ready mix facilities utilize bucket conveyors to move materials. While standard, belted conveyors require substantial run distances for every unit of elevation achieved, a bucket conveyor transports aggregates vertically, with little run distance required. Bucket conveyors consist of buckets, attached to a drive mechanism, such as a chain, that scoop aggregates from a hopper, lift them vertically, and dump them into an overhead storage bin or silo.

2.3 Cementitious Materials

Cementitious materials are the materials that react with water and aggregate to form extensive crystalline structures that give ready mix concrete its high compressive strength. Because of their reactive nature, cementitious materials must be kept dry and protected from the elements. The methods of handling cementitious materials at ready mix facilities are less varied than the methods for handling aggregates. Virtually without exception, cementitious materials are managed in fully enclosed systems – for transportation, receiving, and handling.

2.3.1 Cementitious Materials Types

The cementitious materials used in ready mix concrete production include but are not limited to the following:

- **Portland cement.** This is the most reactive component of Portland cement concrete (ready mix concrete). It is manufactured throughout the world using processes that are not relevant to this manual.
- **Flyash.** Flyash is a byproduct of coal-fired energy production. The use of flyash in ready mix concrete imparts significant benefits to ready mix concrete.
- **Slag Cement.** Some ready mix concrete is produced using ground granulated blast furnace slag, a byproduct of making iron. It, too, has reactive properties and imparts significant benefit to ready mix concrete.

2.3.2 Cementitious Materials Sources

The three cementitious material types cited above are typically sourced from terminals located throughout the State. At these terminals, the cementitious materials are typically stored in fully enclosed above-ground silos.

2.3.3 Cementitious Materials Transportation

Cementitious materials are transported from the respective terminals to the ready mix facility by one of two methods:

- **Over-the-Road Trucking.** The majority of ready mix facilities receive cementitious materials via fully enclosed, air-tight trailers (a.k.a. "pneumatics" or "powder trucks"). While the type of cementitious material may vary and the source of the material may vary, the type of truck is the same – fully enclosed, usually aluminum-bodied trailers, with gasketed closures.
- **Rail.** While not a prevailing operational feature, some ready mix facilities are equipped with rail spurs; those facilities may receive cementitious materials by rail. In these cases, the rail cars function similarly to the fully enclosed, air-tight trailers discussed above.

2.3.4 Cementitious Materials Receiving, Handling, and Storage

Almost without exception, cementitious materials are stored at ready mix facilities in fully enclosed silos. A pneumatic material handling system is used to move the cementitious materials from the delivery vehicle to the storage silo. This pneumatic material handling system consists of truck-mounted and/or plant-mounted blowers, transfer hoses and pipes, and emissions control equipment. The blowers pressurize the delivery vehicle, forcing the cementitious material through the hoses and pipes into the enclosed storage silos. Potential dust emissions from this process are controlled using one of two methods:

- **Bin Vent.** This is a generic industry term for a unit that functions passively or actively to control dust emissions. Essentially a box fitted with cartridge or sock-type filters, the air, pressurized by the materials-handling process, passes through the filtration media, and is discharged to the atmosphere free of particulate matter. The captured cementitious particles fall passively back into the cementitious materials silo.
- **Central Dust Collector.** This unit is essentially a giant vacuum – creating negative gauge pressure at potential cementitious dust emissions points. The ducted air is routed through filtration media and discharged to the atmosphere particulate-free. The recovered particles are driven under air pressure back into a cementitious materials silo.

Several methods are used to move cementitious materials from the storage silos into the ready mix batch process. Prior to being combined with the other ready mix concrete constituents (aggregates, water, admixtures), the cementitious materials must be weighed. To accomplish this, the cementitious material typically 1) passes (passively, by gravity) through some type of gate or valve mechanism or 2) is metered into the weigh hopper using some type of progressive cavity device, such as a material screw conveyor.

2.4 Admixtures

"Admixtures" is a broad, generic term used to describe materials that are added to ready mix concrete to affect strength, workability, consistency, set time, color, curing characteristics, density, permeability, water requirement, and pumpability.

2.4.1 Types of Admixtures

Four general types of admixtures are used in the manufacture of ready mix concrete.

- **Fibers.** Fibers are added to ready mix concrete to improve strength characteristics and control cracking. Fibers take many forms and may be steel, fiberglass, or various synthetic materials, such as plastics.

- **Mineral Admixtures.** Mineral admixtures usually are used to alter the density, strength, or permeability of ready mix concrete. Mineral admixtures also take many forms. Some of the more common mineral admixtures include silica fume, various clay products (e.g., metakaolin), finely ground limestone products, and similar branded products.
- **Color.** Colored concrete is very popular in both commercial and residential applications. Most concrete colorants are iron oxide-containing pigments. These pigments are available in liquid and in dry forms.
- **Chemical Admixtures.** Hundreds of chemical admixtures exist under various branded names that are used to affect the existing properties of ready mix concrete or impart additional qualities to the finished product. These products are available in liquid and in dry forms.

2.4.2 Admixture Batching

Admixtures are added to ready mix concrete in several ways.

- **Plumbed Through the Plant.** Most ready mix facilities have at least some admixtures that are plumbed through the plant and feed directly into the batch process. The batching of these admixtures is typically automated – as part of the overall automated batch process. These installations typically include a number of tanks of bulk admixture products, a control and pump enclosure, and hoses leading either to the plant mixer (Central Mix facility) or to the loading hopper (Transit Mix facility). The inventory of admixture product is replenished periodically by bulk delivery.
- **Fibers.** Most fibers are added manually. Depending on the type of fiber, the amount being added, and the application, the fiber may be manually added directly to the ready mix truck, it may be manually introduced to the plant mixer, or it may be introduced earlier in the batch process, via a weigh hopper or a conveyor.
- **Color.** Color is introduced to the batch process by several methods. Some facilities have automated dispensing systems for liquid or dry color that introduce the colorant directly into the ready mix truck. At other facilities or with seldom-used colors, the colorant may be manually added to the ready mix truck. Colorants are rarely introduced to the batch process prior to a plant mixer because the residual color remaining in the plant mixer may be problematic.
- **Manually Added Admixtures.** Many admixtures, either because of their consistency or the infrequency of use, are simply added manually to the batch process. Again, the product may be manually added directly to the ready mix truck, it may be manually introduced to the plant mixer, or it may be introduced earlier in the batch process, via a weigh hopper or a conveyor.

2.4.3 Admixtures Storage

Bulk liquid admixtures are typically stored in above-ground tanks that feed the admixtures by hose through pumps into the batch process. These tanks may have secondary containment.

Automated dry and liquid color systems are also typically stored in enclosed structures with weighing, metering, and/or pumping systems.

Manually added admixtures are typically stored in site structures to protect from the elements.

2.5 Water

Water is a fundamental raw material for the manufacture of ready mix concrete (along with aggregates and cementitious materials). Water activates the cementitious material and becomes part of the crystalline structure that is developed within the ready mix concrete as the concrete cures.

2.5.1 Sources of Water

Water used in ready mix concrete facilities can be sourced from municipal supply, from groundwater wells, from collected stormwater, and from other plant processes (a.k.a. "process water").

2.5.2 Plant Processes that Produce Process Water

Process water is water that comes into contact with the concrete manufacturing process and is then collected on site in sumps, tanks or lined ponds.

A key process in the manufacture of concrete is the reaction of water with cement, in order to bind the materials together. Water added into the concrete manufacturing process becomes process water. Additionally, water applied to a piece of equipment (truck, plant, etc.) in order to loosen concrete from the equipment is process water. Any water used to wash or clean anything, including washing the ground, on industrial sites should be considered process water.

Please note that rain water falling on a piece of equipment that has been cleaned is not necessarily process water, even if process water has been previously applied to that piece of equipment to clean it. Further, rain water falling on a clean, dry piece of equipment (*i.e.*, no debris or process water remains on it) is unlikely to become process water. However, you should inspect individual machines to determine if there may be remaining process water.

However, any stormwater that comes into contact with process water becomes process water. Therefore, sites will often have distinct areas divided by berms, grade breaks or other means which contain stormwater and process water. Separating the plant footprint into distinct areas limits that amount of process water generated and hence the amount of process water which must be handled.

Plant Mixer Washing. The plant mixer (Central Mix facilities) needs to be rinsed from time to time. The process water generated during this rinsing is collected and transferred into a process-water basin or reclaimer.

- **Loadout Area Dust Control.** The area where the ready mix concrete raw materials (Transit Mix facility) are loaded into the ready mix trucks may use spray bars to suppress dust during loadout activities. This water is process water.
- **Loadout Area Washing.** The area where the ready mix concrete (Central Mix facility) or the ready mix concrete raw materials (Transit Mix facility) are loaded into the ready mix trucks needs to be rinsed from time to time. The water generated during these wash activities is process water.
- **Truck Rinsing.** Following loading, a ready mix truck may need to be rinsed in order to remove concrete or concrete components from exterior truck surfaces. The water generated during these rinse activities is process water.
- **Truck Water Tank Filling.** Ready mix truck water tanks hold water used for job-site load adjustment and/or job-site wash activities. Non-process water is typically used to fill these tanks. When these tanks are overfilled, the spilled water may constitute a process water or a potential

non-stormwater discharge as defined by the California Industrial Stormwater Permit currently ORDER 2014-0057-DWQ. As these permits are amended regularly as required by law, producers should regularly conduct a review of operative permits and determine how these waters are legally defined to ensure compliance.

- **Truck Washout.** At the end of the business day, and frequently at intervals throughout the business day, ready mix trucks need to wash out their drums. The water generated during these truck washout activities is process water.
- **Truck Cleaning.** Drivers often wash their ready mix delivery trucks using a variety of products. Soaps are used for the removal of grime; acids are typically used for the removal of concrete or cementitious material film.
- **Moisture Management: Aggregate Storage & Handling.** Aggregates may be sprinkled with water during storage and/or handling for purposes of 1) maintaining appropriate water content, 2) dust control, or 3) cooling. Excessive use of this water or failure to capture and recycle it may produce a potential non-stormwater discharge.
- **Site Dust Suppression & Yard Maintenance.** At some facilities, water may be used to suppress dust on both drive and non-drive surfaces. Water may also be used to rinse various areas of the plant. Depending on the type of water used and the location of use, the water may be process water or may produce a potential non-stormwater discharge.

2.5.3 Stormwater

Stormwater as referred to in this manual refers to industrial stormwater under the State of California's Current Industrial Stormwater Permit.

2.5.4 Stormwater as Process Water

Stormwater may become process water if: 1) it falls on areas of the facility where process water is present, 2) it falls on areas of the facility where cement or uncured concrete is present, or 3) it comingles with process water.

2.6 Returned Material Management

Ready mix concrete facilities and recycle facilities are challenged with the management of returned material – material that is not used by the customer for whatever reason. Several operational processes are used to manage this returned material.

2.6.1 Stabilization and Resale

State guidance currently allows for stabilization and resale of up to fifteen percent by weight of return concrete, with certain time and notification parameters in place. Stabilization of returned concrete is accomplished using carefully measured doses of retarding chemicals. These chemicals temporarily halt the curing process. The practice of stabilization and resale is not extensively employed, because customers are not generally accepting of the practice, and because of incompatibility among mix designs.

2.6.2 Beneficial Reuse Using Forms

Many ready mix concrete facilities build large concrete blocks or other precast structures with returned concrete using commercially available forms. The finished products can be used to create aggregate bin walls, retaining walls, traffic barrier rails, parking lot bumpers, or rip rap for erosion control.

2.6.3 Reclaimers

Reclaimers are complex equipment packages that segregate returned concrete into 1) screened or unscreened aggregates and 2) cementitious-material-containing process water. The aggregates and process water can then be reintroduced into facility processes.
Reclaimers are expensive to purchase, expensive to install, expensive to operate, and occupy significant space. Despite these drawbacks, reclaimers are often a significant tool in the effective management of returned material.

2.6.4 Beneficial Reuse – Aggregate Base

Market demand for aggregate base made from crushed returned concrete is growing – creating one-for-one conservation of the mining and manufacture of virgin material. Many ready mix and recycle facilities windrow returned material onsite or offsite. Once the material is cured, it is broken up and stockpiled for later incorporation into aggregate base. Sediments removed from the process water basin may be incorporated into the broken-up material.

2.6.5 Disposal

If returned concrete cannot be utilized by any of the methods presented above, the material must be stockpiled onsite for off haul to disposal.

2.7 Facility and Truck Maintenance

Maintenance of the equipment-intensive aspects of the manufacture of ready mix concrete is a necessary part of facility operations. The two are described below.

2.7.1 Facility Maintenance

Ready mix concrete facilities require maintenance.

- **Process Water Basin Maintenance/Sediment Removal.** The process water basins collect aggregates, cementitious materials, and water from plant processes. These materials need to be removed on a regular basis to maintain basin capacity. These materials are typically allowed to drain prior to off-haul for disposal. The materials may be placed so as to drain back into the process water basins, or after free-draining liquid has drained may be placed in the area where return material is windrowed for beneficial reuse.

2.7.2 Truck Maintenance/Loader Maintenance

Ready mix truck maintenance occurs, to some extent, at every ready mix concrete facility where vehicles are domiciled. Many facilities perform only minor maintenance onsite, sending the trucks to in-company or vendor facilities for larger maintenance concerns.

- **Fueling.** Most ready mix delivery vehicles run on diesel fuel. Fueling can occur through onsite facilities, offsite facilities, or vendor-supplied onsite services (a.k.a. “wet hosing”).

- **Lubrication.** The engines, gearboxes, hydraulic units, bearings, and rollers on a ready mix truck require periodic lubrication. This lubrication can be performed onsite by company mechanics, offsite at company or vendor facilities, or onsite by vendor-supplied services.
- **Minor Repairs.** A large number of minor repairs of ready mix trucks are routinely handled onsite by mechanics. These include minor electrical system repairs, light changes, tire changes, etc.

Major Repairs. Major repairs of ready mix trucks may be handled onsite, if the facility is equipped with a maintenance shop. Other facilities handle major repairs through strategically located regional repair facilities or through vendors.

3.0 BEST MANAGEMENT PRACTICES

3.1 Discharge to Local POTW

Discharge to Local POTW

Description

Many local Publicly Owned Treatment Works (POTW) may find it beneficial to accept concrete process water at their water treatment plants. Process water's high pH helps to neutralize the sewage wastes, which are typically acidic (low pH). Discharging off-site directly into the community sewer system can be a win-win for both the facility with limited process water storage capacity and for the POTW.

Applicability	Targeted Constituents	Estimated Costs
☒ All Facilities ☐ New Facilities ☐ Facilities Undergoing Significant Renovation ☐ Facilities Undergoing Minor Site Improvements	⊕ Suspended Solids ⊕ Dissolved Solids – Metals ⊕ Petroleum Hydrocarbons ∅ pH Changes – depending on discharge permit conditions	☐ High Capital $$$ ☒ Moderate Capital $$ ☐ Low Capital $ ☐ High Maintenance $$$ ☐ Moderate Maintenance $$ ☒ Low Maintenance $ ☒ Operational $ -- depending on discharge permit

		conditions

Advantages

- **Reduces Risk of Off-Site/Overflow Discharges .** By discharging the process water as needed to the POTW, a facility can assure that ample on-site storage for excess process water is available and that potential for overflows is minimized, thereby reducing the risk of overflow and unnecessary or unpermitted off-site or overflow discharges. **Reduces Space/Volume Necessary for Excess Process Water Storage.** By discharging to a POTW, a facility can minimize the need for large basins to contain all excess process water. However, on-site basins may still be necessary to allow the settling of solids prior to any excess process water discharge, especially if the applicable permit includes a solids limitation.
- **Low Maintenance.** Pumps and piping will need periodic maintenance. Sediment from the basins and/or storage system may need to be periodically removed.

Limitations

- **Capital Costs.** Costs for permitting, analytical testing, hook-up fees, piping, and potential tanks are moderate. Once the discharge permit has been issued, and the necessary infrastructure is in place, operational costs will be minimal – usually limited to analytical costs and fees assessed based on flow rates and constituent concentrations.
- **Water Use.** If discharging to a POTW, fresh water will need to be sourced from municipal supply or wells – in order to meet operational needs. This can be offset by reuse of process water in facility operations and discharging only when excess process water storage is getting full.
- **Solids Disposal.** As with all settling and containment basins, solids may need to be periodically removed and disposed of appropriately.
- **Effluent Limitations.** As mentioned above, the excess process water will need to meet effluent limitations. The effluent limitations may therefore necessitate pretreatment of the excess process water for reduction of TSS or pH adjustment.

Discharge to Local POTW

Uses/Engineering/Design

- A plant located near sewer pipes that feed to a local POTW may be able to discharge its excess process water under permit to POTW. The community sewer systems are usually operated by municipal, county, or regional sanitation districts. POTWs are regulated by governmental agencies and must implement categorical pre-treatment standards. These standards help the POTW to assure that the discharge into their system will not have an adverse effect on their system and will conform with their Waste Discharge Requirements issued by the Regional Water Quality Control Board.

- A plant seeking to discharge excess process water to a POTW must first initiate contact with the POTW. The POTW's discharge requirements may result in the need for pretreatment of the excess process water or may preclude the discharge entirely. Generally, an application form will need to be completed. The POTW may request water analyses to determine if the excess process water meets effluent standards and permit requirements. If a permit is granted, facilities will have discharge limitations and requirements (possibly including sampling, analysis, and reporting).

- Any discharge limitations will be based on potential excess process water constituents and flow. These may include limits on petroleum products, solids content, discharge rates, heavy metals, oxygen demand, color, temperature, total dissolved solids, pH, etc. In some cases, the permit may only authorize discharges in batches and not authorize continuous flow. Each batch may require a limited analytical analysis prior to discharge. Discharges high in solids content may not be allowed or may be assessed a surcharge based on the amount of solids. Additionally, some POTWs will not accept excess process water that has been comingled with stormwater.

- Plant modifications necessary for implementing discharges to the POTW will include piping into the POTW system and may include storage tanks and/or modification to protect collection & storage areas from stormwater.

- In some circumstances, excess process water can be trucked to the POTW. In these cases, prior arrangements will need to be made with the POTW.

Implementation/Maintenance

- Pumps and piping will require periodic maintenance.
- The basins and storage systems may need maintenance to prevent sediment buildup.

Cost

- Moderate costs will be required for permitting, testing, hook-up fees, piping and potentially additional tanks.
- Operational costs are often minimal and usually limited to analytical testing costs and fees assessed based on flow rate and constituent concentrations.

3.2 Return Concrete Management -Formed Concrete Products

Formed Concrete Products

Background

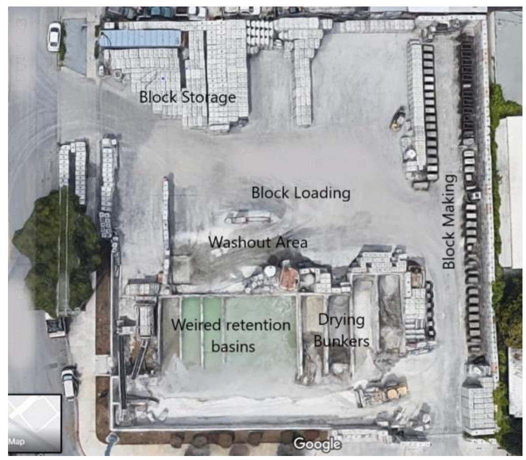
Every ready mix concrete facility has to manage return concrete. In some cases, return concrete is placed in windrows and then reprocessed into a recycled aggregate base product. In other cases, return concrete can be reused in concrete blocks. In larger metropolitan areas, return concrete may be managed at a stand-alone plot of land with its own washout facility serving multiple concrete plants. Proper return concrete management reduces the amount of material entering washout ponds and process water management areas and allows return concrete to be beneficially reused.

Applicability	Targeted Constituents	Estimated Costs
☒ All Facilities	⊕ Suspended Solids	☐ High Capital $$$
☐ New Facilities	⊕ Dissolved Solids – Metals	☒ Moderate Capital $$
☐ Facilities Undergoing Significant Renovation	⊕ Petroleum Hydrocarbons	☐ Low Capital $
☐ Facilities Undergoing Minor Site Improvements	⊕ pH Changes – depending on discharge permit conditions	☐ High Maintenance $$$
		☐ Moderate Maintenance $$
		☒ Low Maintenance $
		☒ Operational $ -- depending on discharge permit conditions

Formed Concrete Products

Description

Many ready mix concrete facilities build large concrete blocks or other precast structures with returned concrete using commercially available forms. The finished products can be used to create aggregate bin walls, retaining walls, traffic barrier rails, parking lot bumpers, or rip rap for erosion control. This practice reduces both environmental and financial impacts associated with returned concrete for the ready-mix producer, while simultaneously creating another product that can be used in many applications.



Facilities engaged in block making will generally have several areas;

- -Form and block making area
- -Block storage and loading area
- -Washout area

The form and block making area will have commercially available forms into which returned concrete can be poured. Once the concrete is poured into the forms, the concrete is left to harden. This area is generally a small padded area often paved and sloped/graded so stormwater that falls on the area flows to a basin or the washout system of the plant/facility.

Once the concrete is cured, the form is opened and the concrete block is then moved to a block storage area with a forklift. The block storage area is where all the finished blocks are kept until they are loaded on to trucks after being sold. When a block is sold, the forklift picks up the block and places it on the trailer for delivery.

After the ready mix truck has poured the concrete into the form, the trucks need a place to wash out the drum. Washout may be done on-site, or in rare instances, may be done at a nearby facility. Washout areas may consist of hoses or overhead piping systems, water tanks, sump basins and pumps, grade changes, and retention basins, which are discussed further in other sections of this manual.

Formed Concrete Products

Advantages

- Cost effective reduction of material in waste stream.
- Full utilization of resources.
- Easy to implement.
- Reduces volume of concrete washout system a plant needs to accommodate.

Limitations

- Need to be able to market products made.
- Area needed grows with plant volume.
- Can outgrow facility footprint storage capacity.

Uses/Engineering/Design

- Compacted or more likely paved pad area.
- Graded or sloped to connect to process water washout area or retention basin.

Implementation and Maintenance

- General housekeeping sweeping cleaning of area to prevent buildup of lose material.
- Possible maintenance of pipes or channels connecting area to washout area/retention basin.

Cost

Low – System, if able to be implemented, turns return concrete into a manufactured product.

3.3 Housekeeping

Housekeeping

Description

Consistent housekeeping at a ready mix concrete facility will have beneficial effects for areas within and outside of the process water footprint. Certain pollutants make process water less attractive for reuse or treatment.

Inconsistent housekeeping will have a negative impact in a plant's stormwater area; however this BMP is confined to the process water footprint.

Applicability	Targeted Constituents	Estimated Costs
☒ All Facilities	⊕ Suspended Solids	☐ High Capital $$$
☐ New Facilities	⊕ Dissolved Solids – Metals	☒ Moderate Capital $$
☐ Facilities Undergoing Significant Renovation	⊕ Petroleum Hydrocarbons	☒ Low Capital $
☐ Facilities Undergoing Minor Site Improvements	⊕ Oil and Grease	☐ High Maintenance $$$
		☒ Moderate Maintenance $$
		☒ Low Maintenance $
		(see discussion under Limitations)

Housekeeping

Advantages

- **Reduce Track-Out.** Consistent application of good housekeeping practices will reduce transfer of contaminants from the process water footprint into stormwater portions of the ready mix concrete facility.
- **Promote Housekeeping Awareness.** Consistent application of good housekeeping practices keeps the site looking well-organized to visitors and reinforces good housekeeping skills to employees. Regular training on procedures keeps employees aware of the purpose and importance of maintain good housekeeping.
- **Safety.** It has been proven that facilities with good housekeeping have safer work records, as slip, trip, and fall hazards are eliminated or made easier to see and evade.

Limitations

- **Street Sweeper Costs.** Street sweepers can be purchased, or the service can be outsourced. If the unit is purchased, the capital cost can be substantial, and maintenance costs can be significant. If the service is outsourced, maintenance costs disappear, but the per-event charges can add up over time. Disposal of the swept up material should be planned for, since offsite disposal can be expensive.
- **Air District Requirements.** Some air districts mandate sweeping as a BMP for control of emissions. The ready mix facility operator must be familiar with air district requirements, and be prepared to comply with all such requirements prior to committing capital for a sweeper purchase. For example, one air district in the south requires a particular type of PM-10 filtration.

Uses/Engineering/Design. Not applicable.

Implementation/Maintenance

Typical housekeeping procedures include training, sweeping paved areas, managing covered trash receptacles, secondary containment, maintaining spill response equipment,

- **Training.** Training is one of the most essential aspects of housekeeping. All personnel, including ready mix truck drivers, plant personnel (batchpersons, materials handlers), fleet and plant maintenance persons, bulk delivery personnel (cementitious, aggregate, admixture, petroleum product, etc.), and outside contractors should be cognizant of facility operations. A basic tenet of this training should be "Recognize and Report," i.e., if something doesn't look quite right, it should be reported.

- **Sweeping.** Sweeping paved areas can be accomplished manually or with a street sweeper, depending on the facility size. It is recommended that sweeping be performed on a regular basis, and that a log of sweeping activities be maintained according to the various applicable regulatory agency requirements.
- **Trash Receptacles.** Trash receptacles should be kept closed to prevent any water from getting into the container and leaching out possible pollutants. This also prevents wind from blowing trash or solids out.
- **Hazardous Materials.** At a minimum, hazardous materials containers should be kept closed, appropriately labeled, and properly stored according to applicable regulations.
- **Secondary Containment.** The purpose of secondary containment is to prevent leaking containers from contaminating process water or the process water footprint area. Secondary containment can take many forms, such as concrete curbing, double-walled tanks, retrofits to existing tanks (e.g., commercially available spill pallets or similar), or enclosed cargo containers. The specific form of secondary containment should be matched to plant use, container contents, and climatic conditions.
- **Spill Response.** Prompt response to spills is essential to reduce possible contamination within the process water footprint. Training employees to quickly respond to spills and utilize spill kits is essential. Spill response supplies that provide dry clean-up methods for addressing spills or leaks of hazardous materials from equipment or trucks must be kept available, labeled, and protected. Employees should be familiar with the various procedures required to address different kinds of spills, such as petroleum products, hazardous materials, liquid color, admixtures, etc.

- **Cementitious Spills.** Spills of cementitious materials occurring during delivery of these materials are a common problem at ready mix concrete facilities. Because of the finely divided nature of these products, they can easily be wind-blown or tracked throughout the facility. Therefore prompt dry-cleanup methods must be employed as soon as any such spill is noted.
- **Neatness.** An extension of good housekeeping practices is the safe, orderly, and operationally efficient management of all materials, supplies, and equipment throughout the facility – from aggregates to dry admixtures to plant repair tools/parts to truck cleaning materials. Where feasible, storage should be protected from the weather. Appropriate and timely disposal of outdated and derelict materials and supplies should occur.

Costs

- **Cost vs. Benefit.** Costs are highly site-specific. BMPs with higher capital or maintenance costs can frequently be amortized over several facilities, such as might occur with a single street sweeper used at multiple sites. Overall, the benefits of good housekeeping, such as enhanced safety and regulatory compliance, typically far outweigh the costs.

Housekeeping

Secondary containment for hazardous materials

Secondary containment for Admixtures

Housekeeping

Trash receptacles closed.

3.4 Inspection and Maintenance

Inspection and Maintenance

Description

Plants should implement a comprehensive inspection and maintenance program to ensure the process water management features and infrastructure is properly functioning.

All inspection and maintenance activities must be documented to demonstrate compliance with the facility's applicable permit requirements.

A well-managed inspection and maintenance program will minimize the potential impact to surface water and ground water resources.

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Applicability	Targeted Constituents	Estimated Costs
☒ All Facilities	⊕ Suspended Solids	☐ High Capital $$$
☐ New Facilities	⊕ Dissolved Solids – Metals	☐ Moderate Capital $$
☐ Facilities Undergoing Significant Renovation	⊕ pH Changes	☒ Low Capital $
☐ Facilities Undergoing Minor Site Improvements		☐ High Maintenance $$$
		☐ Moderate Maintenance $$
		☒ Low Maintenance $

Inspection and Maintenance

Advantages

- **Reduces maintenance cost.** By actively observing, inspecting and documenting the condition and performance of the process water management features and infrastructure, deficiencies will be identified early and allow for proactive and timely repairs.
- **Catches problems early.** By inspecting and documenting the condition and performance of the process water management features, potential non-containment of process water will be identified, basin over topping or process water non-containment can be quickly addressed to minimize potential down gradient soil impacts and/or potential impacts to surface and/or ground water.
- **Low Maintenance.** Daily observations and periodic inspections are part of the operation of any concrete plant and have the potential to minimize operational costs.

Limitations

- **Operations.** The observations are limited to days the facility is operating and when employees are on-site.
- **Training.** Training is required.
- **Recordkeeping.** Current and accurate records need to be available according to permit requirements.

Uses/Engineering/Design

- The documented observation and periodic inspection program must be permit-compliant. Additional inspection is recommended, such as a detailed daily inspection of the process water containment area to identify signs of potential basin over topping or water releases as appropriate. The inspection log should also include a list of the maintenance responses to correct any deficiencies observed.

Implementation/Maintenance

- The daily inspection log should be conducted each day of operation and should clearly list the following items, in addition to any items required under permit terms, associated with the process water management features and infrastructure, with a description of how they are functioning, and any remedial measures implemented.

- Observe basin water level and adequate free board.
- Evaluate sediment accumulation vs. pond sediment capacity.
  - Inspect visible side walls (free of cracking or damage).
- Inspect visible concrete pads and sediment drying areas (free of cracking, appropriate drainage direction, adequate curbing).
- Observe surrounding soil surfaces for signs of overflow. Look for process water staining, erosion, sediments.
- Observe all means of process water conveyance, including pumps, piping, swales, curbs, and berms.

3.5 Mixer Truck and Concrete Pump Washout

Mixer Truck and Concrete Pump Washout

Description

The operative factor of good truck or pump washout is to discharge all remaining concrete from the truck or pump prior to washout. This process will minimize the quantity of water necessary to achieve efficient drum cleaning, and will reduce the amount of concrete paste in the resulting washout water and, therefore, proportionately reduces the TDS, TSS, and pH. Minimizing water use for washout also results in less process water that must be stored for reuse, treatment, or disposal..

Applicability	Targeted Constituents	Estimated Costs
☒ All Facilities	⊕ Suspended Solids	☐ High Capital $$$
☐ New Facilities	⊕ Dissolved Solids – Metals	☐ Moderate Capital $$
☐ Facilities Undergoing Significant Renovation	∅ Petroleum Hydrocarbons	☒ Low Capital $
☐ Facilities Undergoing Minor Site Improvements	∅ pH	☐ High Maintenance $$$
		☒ Moderate Maintenance $$
		☐ Low Maintenance $

Mixer Truck and Concrete Pump Washout

Advantages

- **Useful at a Wide Varity of Facilities.** The reduction of solids in the truck drum or pump prior to washout will be beneficial, to some degree, at almost all facilities. The best results will be achieved when used in conjunction with other BMPs, such as windrowing pad and process water basin, where settled process water can be reused.
- **Simple concept.** The concept of "Empty Truck, Little Water" is easy to communicate. This will simplify the training process for plant personnel.
- **Moderate Maintenance.** If properly executed, a minimum washout program itself requires no maintenance. At a facility where no windrow pad or process water system exists, however, the plant must implement and maintain a system to handle the returned concrete removed from the truck or pump prior to washout and properly store and handle the process water.

Limitations

- **Consistency of Execution.** Although the concept of "Empty Truck, Little Water" is simple, the repetitive training required to produce consistent results can sometimes be daunting. A system of training and monitoring that must be set up can increase the time burden on an often already fully committed plant manager.
- **Must Be Part of an Overall Plant System.** Truck or pump washout cannot be a stand-alone system. If all returned concrete must be removed from the drum or pump prior to washout, it follows that some method of handling that material must first be in place. This can take many forms: a windrow pad; block forms; or off-site disposal, such as a nearby recycling yard. Likewise, even the reduced amount of process water must have an in-place system to receive it.

Uses/Engineering/Design

- No direct engineering is required. However, as discussed above, the ability to remove and properly handle returned concrete from the truck or pump prior to washout and properly contain the resulting process water must be in place. These systems often require engineering and design.

- **Process Flow Considerations.** For a truck or pump washout system to be successful, it must be convenient to use and fit into the overall process flow of the plant. Returned concrete removal, the source of the water used for truck washout, and the location of the process water discharge must all be in close proximity. If these components are widely separated, operating costs and the process water footprint will increase.

Implementation and Maintenance

- If properly executed, a minimum washout program itself requires no maintenance. At a facility where no windrow pad or process water system exists; however, some system of handling the returned concrete removed from the truck or pump prior to washout and properly storing and handling the process water must be implemented and maintained.

Cost

- **Capital Costs.** Minimizing truck or pump washout, by itself, has no capital costs. However, as discussed above, associated returned concrete and waste water handling systems may require capital, if not already existing.
- **Maintenance Costs.** Maintenance costs in the form of employee training and management time can be significant. Please consult the Training BMP for further information.

3.6 Mixer Truck Water Use

Mixer Truck Water Use

Description

Drivers are normally responsible for filling saddle tanks, adding water to the drum, exterior truck rinsing and truck washout (washout refers to truck drum interior rinsing). Overflows and excess water usage can generate more water than the process water management system was designed to handle and thus overtax the system. Municipal supply/well water can be very expensive if not properly controlled. Water management has a significant impact on efficiencies and costs. Effective BMPs, as described within, will help to reduce or eliminate these problems. Depending on the level of control desired, the cost to institute these BMPs ranges from low capital expenditures, to moderate capital expenditures.

Applicability	Targeted Constituents	Estimated Costs
☒ All Facilities	⊕ Suspended Solids	☐ High Capital $$$
☐ New Facilities	⊕ Dissolved Solids – Metals	☒ Moderate Capital $$
☐ Facilities Undergoing Significant Renovation	⊕ Petroleum Hydrocarbons	☒ Low Capital $
☐ Facilities Undergoing Minor Site Improvements	⊕ pH Changes	☐ High Maintenance $$$
		☐ Moderate Maintenance $$
		☒ Low Maintenance $

Mixer Truck Water Use

Advantages

- **Prevents Overtaxing of the Process Water Management System.** Creating more water than the process water system was designed for is often difficult to manage. In some cases, this can result in off-site discharges of process water. Limiting the amount of municipal supply/well water spilled during saddle tank filling, exterior drum and truck rinsing, and minimizing the use of municipal supply/well in truck washout will help prevent overtaxing the process water system and reduce the potential for process water discharge.
- **Reduces Costs.** Municipal supply/well water can be very expensive, therefore, reducing excess usage of municipal supply/well water will decrease purchase costs, treatment costs, and make the plant more efficient. Likewise, minimizing the volume of process water that must managed by the process water system can reduce capital and maintenance costs and reduce the process water footprint.

Limitations

- **Capital Costs.** Some of the BMPs listed below have very low costs. More robust BMPs will require a moderate capital expenditure.
- **Level of Adherence.** As mentioned above, some of the BMPs have very low costs, such as driver training. The lower cost BMPs are more prone to human error. Technology based BMPs reduce the possibility of human error, but typically increase the costs.
- **Siting Considerations and Space Requirements.** Depending on which BMP is used, siting and space requirements will be limited.

Uses/Engineering/Design

The following BMPs can be used separately or in conjunction with each other to effectively manage water usage when filling saddle tanks, adding water to the drum, truck and drum rinsing, and truck washout.

- **Driver Training.** Drivers should be continually trained regarding appropriate water usage and the consequences of excess water usage. The training should focus on using just enough water to adequately get the job done.

Mixer Truck Water Use

- **Installation of Water Shut-Off Valves.** Conveniently located water shut-off valves on water hoses used to fill tanks is an effective tool to prevent over-filling of the tanks. For example, an automatic shut-off valve can prevent overflow to the truck's water saddle tank. As the tank fills with water, internal air pressure increases. When the air pressure reaches a certain level, a pressure switch activates an electric solenoid-actuated water valve that shuts off the water source. Likewise, spring-loaded shut-off valves can minimize water spillage.
- **Overhead Drum Filled With Metered Water.** Overhead drum filling stations (for load adjustment) help to ensure all water being added is directly discharged into the drum and not spilled outside the drum. Metered valves can be used to control the amount of water being added.
- **Use High Pressure, Low Volume Nozzles.** High pressure, low volume nozzles can be used during truck and drum rinsing to effectively limit the amount of water used. Computer controlled systems can be used with this and in conjunction with the overhead fill that restricts the amount of water that can be used.
- **Overhead Spray Bars.** Overhead spray bars, using high pressure, low volume water can also be used to limit the amount of water used for truck rinsing.
- **Capture Rinse Water for Reuse.** Truck rinse water is process water and can be reused for slump adjustment, for truck washout, or for batching. Depending on the solids content of the water needed for batching, the process water may need to be clarified, e.g., by filtration or using weired process water basins.
- **Limit Drum Rinse Water.** Mixer drums should be only rinsed as operationally necessary, such for changing mix designs, concrete colors, to limit buildup potential, or at the end of day. Reused process water should be utilized for truck washout and the amount of water should be limited to that which is operationally necessary, from 150 – 300 gallons for each drum washout. Too much water in the drum can reduce the cleaning action of the tumbling water in the drum. As with the BMPs listed above, installing flow control nozzles on the water

hoses at the rinse station and limiting washout time can minimize water usage.

- **Rock Out Drums** See the "Rock Out" BMP as an effective way to reduce/eliminate water used for drum washout.

Implementation/Maintenance

- See Uses/Engineering/Design above.
- Maintenance will be low to moderate depending upon the specific BMP activities that are implemented.

Cost:

- Costs will be low to moderate depending upon the specific BMP activities that are implemented.

3.7 Process Water Reuse

Process Water Re-Use

Description

The re-use of process water in ready mix concrete facility batch processes is fundamental in the management of process water. In the absence of beneficial re-use, a facility's only other option for the disposition of process water may be discharge to a sanitary sewer system.

Various aspects of well-planned capture, containment, and possible treatment of the process water are covered in the other BMPs in this manual. The scope of this BMP is to provide a high-level overview of a process water re-use plan.

Water other than tap can be used as mix water in ready mixed concrete as long as the producer follows procedures in ASTM C1602 and ASTM C94 in order to ensure water quality meets standardized limits.

Applicability	Targeted Constituents	Estimated Costs
☒ All Facilities	⊕ Suspended Solids	☒ High Capital $$$
☒ New Facilities	⊕ Dissolved Solids – Metals	☐ Moderate Capital $$
☒ Facilities Undergoing Significant Renovation	⊕ Petroleum Hydrocarbons	☐ Low Capital $
☒ Facilities Undergoing Minor Site Improvements	⊕ pH Changes	☐ High Maintenance $$$
		☐ Moderate Maintenance $$
		☒ Low Maintenance $

Process Water Re-Use

Advantages

- **Water Conservation/Costs.** Many facilities either purchase source water or pump it from wells. Using process water from ponds reduces or eliminates purchased water and reduces pumping costs from deep water wells. Reusing storm water also reduces drawdown from groundwater aquifers and/or conserves water treated for human consumption.
- **Reduces the Potential Off-Site Discharges of Co-Mingled Water.** Containing process water and reusing it will also help to ensure that storm water is not co-mingled with process water and allowed to discharge off-site. Re-using process water helps to draw down stored water in the containment structures, thus minimizing the possibility of overtaxing these structures and having an unauthorized release of process water.
- **Low Maintenance.** Depending on the system used, the maintenance of a process water reuse system can be low. Pumps and piping will need to be periodically maintained. Specific gravity meters will need to be calibrated and periodically maintained as well. Weired basins will need to be cleaned periodically – and storage tanks may likewise require periodic cleaning.

Limitations

- **Capital Costs.** Costs for the piping, pumps, specific gravity meters, and control board modifications are high for some facilities. Tanks may also be used in conjunction and are also moderate to high expenses depending on size of facility.
- **Size and Siting Requirements.** The size requirements for this process are minimal – with the exception of weired basin installation. For the most part, existing basins can be used with the addition of plumbing apparatuses. In some cases, additional tanks may need to be employed, which will add to the space requirements.
- **Quality Control.** As mentioned above, the water should be analyzed by checking for any impurities that may adversely affect concrete quality in accordance with ASTM C1602 and ASTM C94.

Process Water Re-Use

Uses/Engineering/Design

An article published by the National Ready Mix Concrete Association (NRMCA) and reprinted with permission regarding the technical aspects of process water reuse is included as Appendix 3 to this document.

- **Process Water Minimization.** The volume of process water generated should be limited using all available technologies and practices. Process water minimization is accomplished through:
    - Process Water Footprint Minimization. The smallest feasible footprint for process water generating operations at a ready mix facility will minimize the volume of process water generated during rainfall events.
    - Facility Layout. By locating process water generating operations within close proximity to each other and to the ready mix batch plant, space is economized and the amount of process water generated from rainfall events will be minimized as well. Additional considerations include on-site grading, which should allow water to flow by gravity to collection sumps to minimize the number and use of electric pumps.
    - Hoses. By limiting the flowrate at truck rinse areas – optimally by replacing hoses with pressure washers – the amount of process water generated can be reduced dramatically.
    - Washout. By utilizing captured and contained process water to wash out the ready mix truck drums, the amount of process water generated can be reduced dramatically.
- **Process Water Treatment.** Process water contains substantial quantities of fine material – which consists of various cementitious and fine aggregate particles. The presence of the particles in higher concentrations can have a detrimental effect on ready mix concrete: these particles may unacceptably increase the rate of curing of the concrete. In addition, this fine material can contribute to the weight of the finished product. Treatment options include:
    - Clarification. The use of properly designed weired clarification basins can reduce the concentration of suspended solids in process

water to acceptable levels. The design of a clarifier system is critical to reusing process water. The clarification system must be large enough to provide enough settling time to allow suspended sand and cement particles to sink to the bottom of settling basins. Care should be taken to ensure that once process waters are clarified that settled solids are not disturbed in such a way as to resuspend solids.

- Filtration. Various types of filtration mechanisms are available to remove suspended solids from process water. These can be expensive to install and maintain.
- Retardation. Most ready mix facilities inventory a retarding admixture for use in ready mix concrete. Addition of retarder to solids-containing process water can offset the set-accelerator characteristic of suspended-solids-containing process water.

- **ASTM Guidelines.** ASTM has published standards for the reuse of process water in ready mix concrete operations. Because of copyright considerations, these standards are not reproduced here; the reader is referred to the ASTM website for the purchase of these standards. ASTM C1602 and ASTM 92 are the applicable standards.

Implementation/Maintenance

See Uses/Engineering/Design

Cost

High

Process Water Re-Use

Process Water Equipment for Washout of Mixer Drum

Process Water Re-Use

Ready Mix Truck Receiving Reclaimed Water for Washout

3.8 Process Water Segregation-Permanent

Process Water Segregation Permanent

Description

Process water segregation employs permanent or semi-permanent physical constructs to segregate excess process water from stormwater falling on areas not impacted with cementitious materials. These physical constructs may consist of grade breaks, drainage swales, and roll curbs or formed curbs.

Mechanical devices, usually pumps, may be necessary to move water between or among areas where process water collects.

This practice can be implemented during the design and construction phases for new facilities; or during design, demolition, and reconstruction phases, for facilities undergoing significant renovation.
Similar practices for facilities undergoing minor site improvements are considered under a separate BMP.

Applicability	Targeted Constituents	Estimated Costs
☐ All Facilities ☒ New Facilities ☒ Facilities Undergoing Significant Renovation ☐ Facilities Undergoing Minor Site Improvements	⊕ Suspended Solids ⊕ Dissolved Solids – Metals ⊕ Petroleum Hydrocarbons ⊕ pH Changes	☒ High Capital $$$ ☒ Moderate Capital $$ ☐ Low Capital $ ☐ High Maintenance $$$ ☐ Moderate Maintenance $$ ☒ Low Maintenance $

Process Water Segregation Permanent

Advantages

- **Passive System.** If properly designed and implemented, the physical constructs or improvements necessary to effect process water segregation function passively. All systems should be designed so that process water and stormwater areas are physically separated with barriers to prevent co-mingling.
    - Process Water Areas. Excess process water and stormwater falling on these areas are passively diverted to collection and storage – for ultimate reuse in batch processes.
    - Non-Process Water Areas. Stormwater falling on areas without cementitious material impacts is likewise passively diverted – to non-process water areas – for collection and possible storage, treatment, and discharge or subsequent use.
    - Integration with Other BMPs. When the design of process water segregation features is coordinated with the design of certain other BMPs, such as process water footprint evaluation and confinement, weired process water basins, bio/filtration basins or swale designs for stormwater, the integrated water management systems enhance the passive function of process water segregation features. Conversely, in the absence of good design considerations, individual components of the integrated water management system can be overwhelmed by the flows of water from either the process areas or the non-process water areas – resulting in comingling of excess process water and stormwater.
- **Low Maintenance.** The process water segregation features in new facilities and in facilities undergoing significant renovation are typically permanent or semi-permanent. For example, a grade break, curb, or drainage swale built in to a paving design typically survives the rigors of plant operations for many years.
- **Low to Moderate Cost.** The low-to-moderate-cost evaluation for process water segregation features presupposes that (in new facilities or in facilities undergoing significant renovation) an area in which a grade break, curb, or drainage swale is to be installed would otherwise be receiving a paving treatment. In such a scenario, the additional

cost to implement process water segregation would consist of an incremental engineering cost and an incremental cost in the pavement placement and finishing.

Limitations

- **Engineering.** The primary limitation to effective process water segregation as presented in this BMP is the need for engineering evaluations early in the design phase.

Uses/Engineering/Design

- **Engineering.** For proper design and implementation, the physical constructs or improvements necessary to effect process water segregation require engineering evaluation(s).
  - Sizing. The sizing of downstream collection, storage, and/or treatment systems for the flows of water generated from inside and outside of process water segregation features require an engineering evaluation that includes the intensity (both duration and rainfall rate) of periodic rainfall maxima, aerial extents of process water and low-impact stormwater runoff collection areas, and operational cycles (for consideration of the amount of collected water that can be reused in batch plant processes). Note that comprehensive site water management evaluations are presented in BMP – Water Management Evaluation.
  - Flowrates. The flowrates of water being directed to collection, storage, and/or treatment systems will determine the necessary sizing of conveyance swales and/or pipes. Water flows entering storage and/or treatment systems at flowrates greater than design could cause scouring of non-paved areas, excessive transport of suspended solids, and overwhelming of treatment systems.
- **Elevations.** A primary consideration for design of a process water segregation feature is elevation. The elevation of the grade break or top of the curb should be greater than the elevation of the ultimate collection/storage feature (e.g., in-ground basin), and accommodate a minimum slope of one to two percent from the feature to the basin. Additional elevation may be required to allow some freeboard water

storage capacity, depending on the design criteria for total storage capacity.

- **Traffic.** A secondary consideration for design of a process water segregation feature is the type of traffic it must be able to withstand and allow to pass. If delivery vehicles, loaders, and/or parking lot sweepers are to pass over the feature, then the feature should either be a grade break or a roll curb. In areas where vehicle traffic is not a concern, but where freeboard capacity may be, a traditionally formed curb, integral or sealed to the surface beneath, is an alternative worth considering.
- **Construction.** Construction of a process water segregation feature is straightforward:
  - Grade Break. If the process water segregation feature consists of a grade break, then it, and the accompanying slopes away from it, are designed into the paving, and likely into the underlying grading.
  - Curb. If the process water segregation feature consists of a curb (whether roll or formed), then the curb may be poured integral to the paving surface. Alternatively, the curb may be poured or tooled on the surface of the underlying paving. If poured or tooled on the surface of the underlying paving, a seal between the two is recommended if ponded water is expected on either side of the feature. If traffic over the roll curb is expected, underlying pavement may need to be notched to prevent movement of the curb.

Implementation and Maintenance

- **Integrity.** Permanent or semi-permanent process water segregation features require little maintenance. Periodic inspections need to be performed to ensure integrity. Elevation or grade breaks built into existing paving design require virtually no maintenance. Roll curbs and formed or tooled curbs should be regularly inspected – as part of the SWPPP inspection protocol – for wear, breaks, and movement.

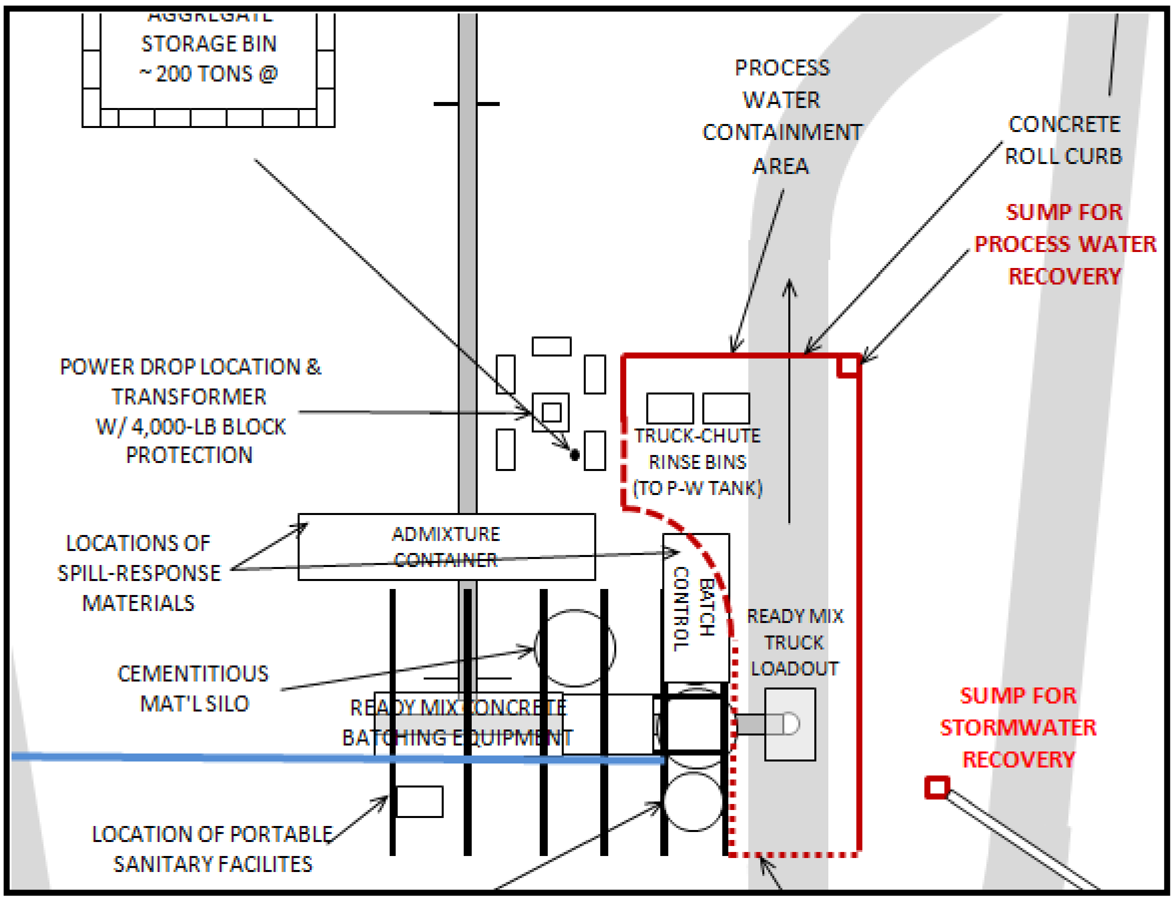
Process Water Segregation Permanent

All Cementitious Process Activities Occur within Containment Area

Process Water Segregation Permanent

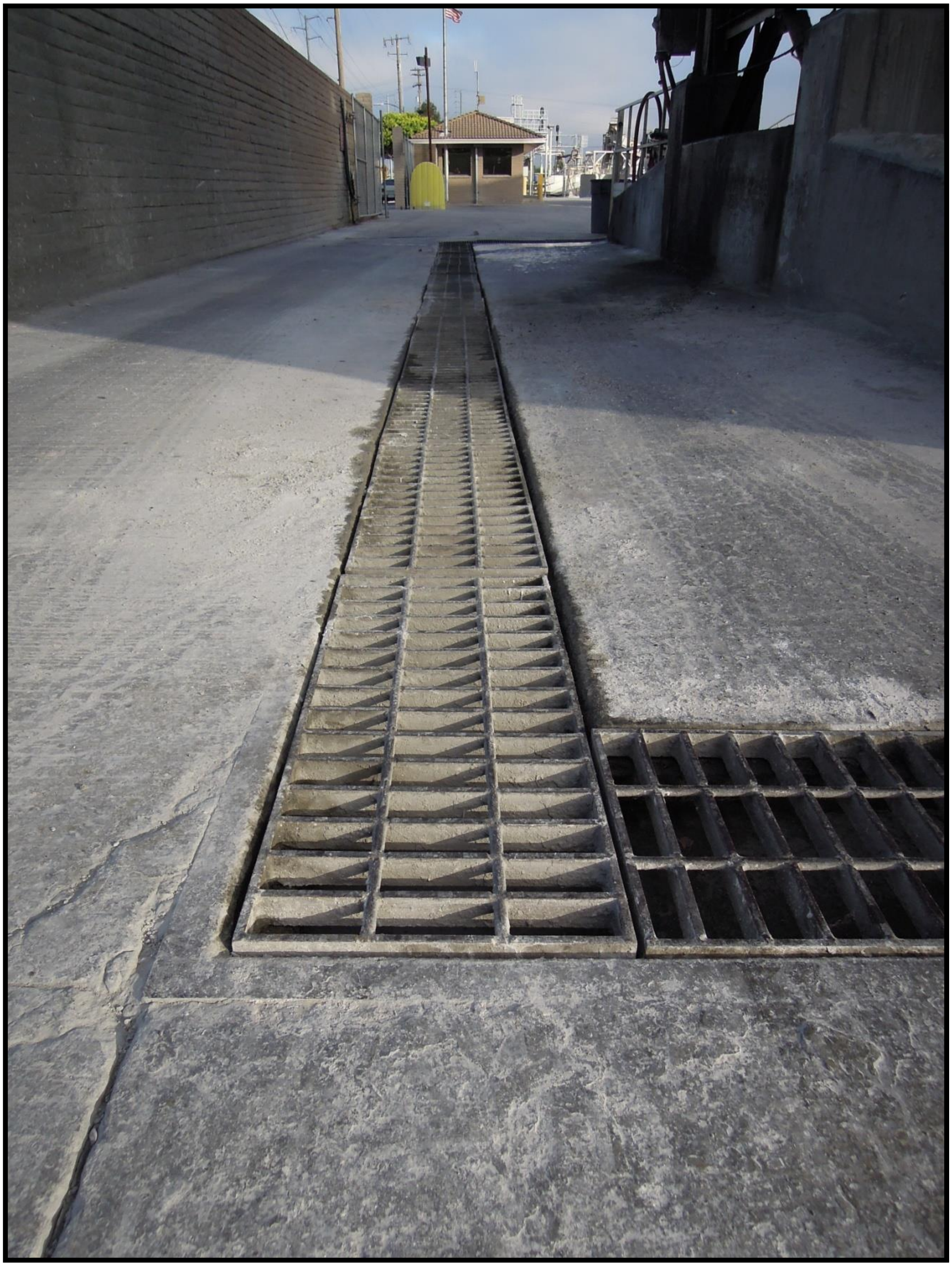
Cost

- **Moderate to High Capital Costs.** The costs for implementation of this BMP are only incremental when the process water segregation features are incorporated into the overall facility design early in the planning process.
- **Low Maintenance Costs.** Maintenance costs are very low and usually consist of inspection and cleaning.



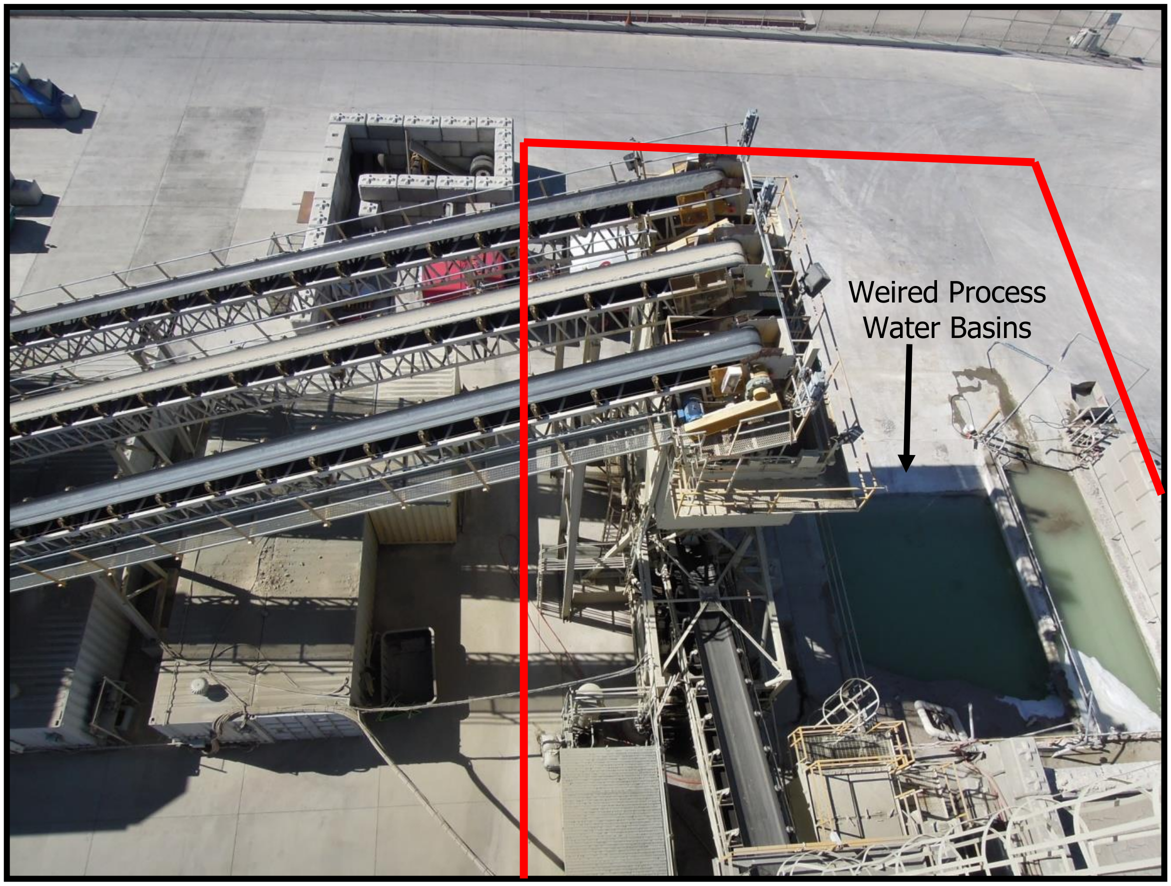
Site Sketch Showing Process Water Footprint Area

Process Water Segregation Permanent



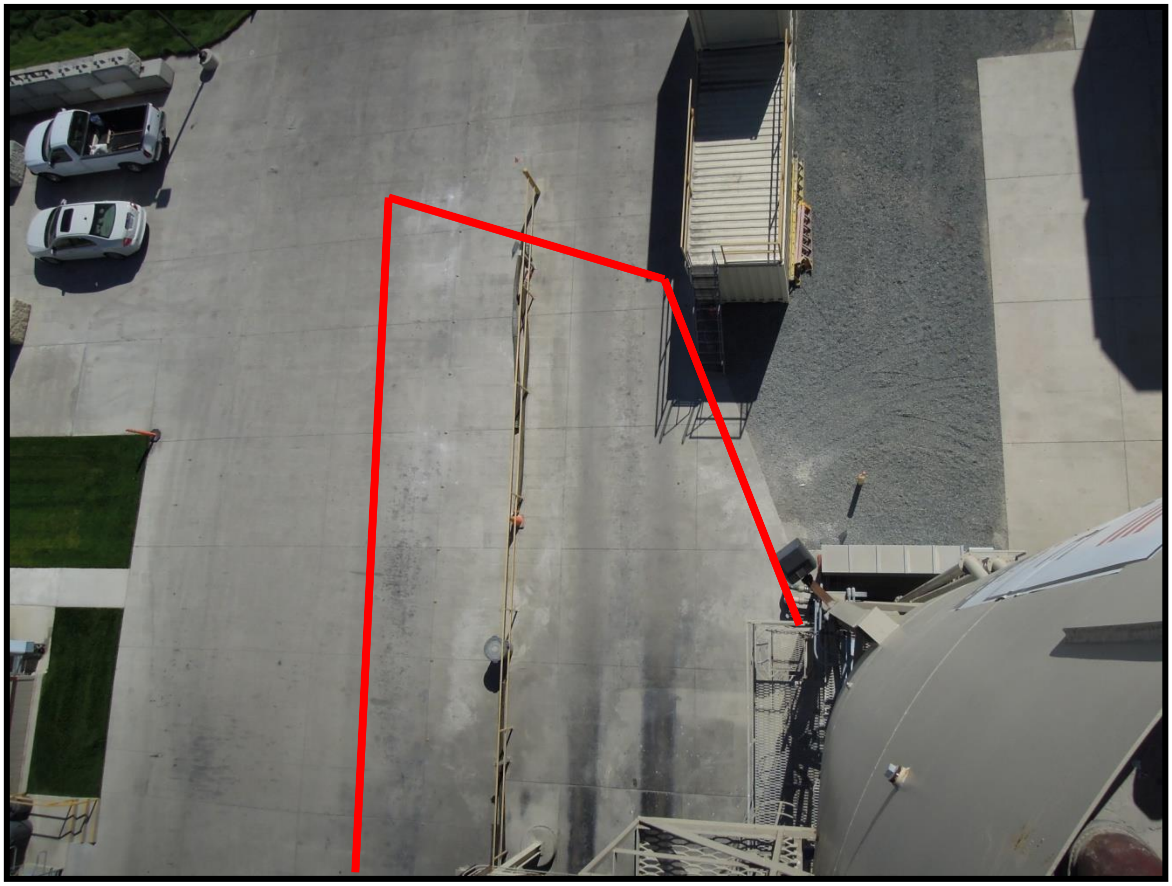
In-Ground Process Water Capture Trench

Process Water Segregation Permanent



Grade Break for Process Water Containment (from above)

Process Water Segregation Permanent



Grade Break for Process Water Containment (from above)

3.9 Reclaiming Systems

Reclaiming Systems

Description

Mechanical reclaiming systems manage returned/excess concrete by separating aggregates from cement/water slurry. A well-managed and maintained system allows for all constituents in the concrete (including the cement/water slurry) to be individually recycled.

Excess concrete is typically discharged into a hopper which feeds into a screening system that washes and separates the aggregates from the cement/water slurry. Secondary screening may separate the aggregates by size into coarse and fine.

The cement/water slurry that is left can be further processed by settling or clarification – the water can either be recirculated back to the reclaimer to wash incoming material or, if of sufficient quality, can be used in batch processes.

Applicability	Targeted Constituents	Estimated Costs
☐ All Facilities	⊕ Suspended Solids	☒ High Capital $$$
☒ New Facilities	⊕ Dissolved Solids – Metals	☐ Moderate Capital $$
☒ Facilities Undergoing Significant Renovation	⊕ Petroleum Hydrocarbons	☐ Low Capital $
☐ Facilities Undergoing Minor Site Improvements	⊕ Oil and Grease	☒ High Maintenance $$$
		☐ Moderate Maintenance $$
		☐ Low Maintenance $

Reclaiming Systems

Advantages

- **Cost Savings.** Reclaimers can provide significant savings depending on site-specific operations. The reclaiming of aggregate produces high quality material since it has been re-washed and can be blended directly with production aggregate storage.
  - Reclaimers reduce the cost of purchased aggregate and sand.
  - Reclaimers reduce the cost of hauling returned concrete to a disposal or recycling facility.
  - A cost analysis can be used to determine if a mechanical reclaiming system is cost effective for a specific operation. The capital and maintenance costs should be off-set by the savings of reclaiming aggregate. The analysis should take into consideration the delivered cost of aggregate and the cost for disposal of returned concrete.
- **Process Water Footprint Reduction.** When functioning properly, some reclaimers can reduce the overall area required for the management of process water.

Limitations

- **Potential Limitations.** Reclaimers, if not properly engineered and integrated with other existing or proposed facility elements, can present several limitations. Many of these potential limitations can be minimized or eliminated with adequate planning and engineering. These potential limitations include time and throughput constraints, site considerations, weather influences, effects on mix designs, and solids drying characteristics. These potential limitations are further discussed in the Uses/Engineering/Design section, below.

Uses/Engineering/Design

- **Time and Throughput Constraints.** Reclaimers have throughput specifications that may limit the time it takes to unload concrete. Consideration should be made of the capacity of the system before purchase, particularly if a cement-water slurry tank is utilized to clarify the water. An appropriate system should be designed specific to an operation to avoid delays in production.

- **Site Considerations.** Reclaimers on their own do not have a large footprint, however, in most cases they should ideally be collocated adjacent to the weired process water basin or other process water management system. The addition of a clarifying slurry water tank and associated admixture storage will also increase the footprint of the system.
- **Weather Influences.** Reclaimers require a significant amount of water to operate. Operation can be difficult during winter seasons if the process water management system is already stressed.
- **Effects on Mix Designs.** The solids content of the cement/slurry water, even after clarification, may have predictable but undesirable effects on the ready mix concrete characteristics.
- **Solids Drying Characteristics.** The settled, dewatered cement fines take considerable time to dry. Additional space and/or weather protection will likely be required.

Implementation/Maintenance

- Reclaimers require regular equipment maintenance as well as process management of the system to ensure that the drivers do not overload it.

Costs

- **High Capital Costs.** Mechanical reclaimers are available with varying throughput capabilities that are correlated to both plant throughput and fleet size. Virtually without exception, reclaimers will require high capital costs to purchase and install.
- **High Maintenance Costs.** Reclaimers require regular equipment maintenance as well as facility operator management of the process. A well-managed system will require additional time from employees or may require a dedicated employee to ensure the system is used and maintained properly and not overloaded by the drivers.

3.10 Returned Concrete Windrowing

Returned Concrete Windrow

Description

Many concrete producers and construction material recyclers process returned concrete by allowing it to cure to a hardened state prior to beneficial reuse as a component of a manufactured aggregate base.

This BMP discusses proper methods for pouring the concrete into long narrow piles (windrows) that will promote quick hardening of the returned concrete and allow for easy pickup and placement into a rubble pile for further processing (on- site or off-site).

Applicability	Targeted Constituents	Estimated Costs
☒ All Facilities ☐ New Facilities ☐ Facilities Undergoing Significant Renovation ☐ Facilities Undergoing Minor Site Improvements	⊕ Suspended Solids ⊕ Dissolved Solids – Metals ⊕ pH Changes	☐ High Capital $$$ ☐ Moderate Capital $$ ☒ Low Capital $ ☐ High Maintenance $$$ ☒ Moderate Maintenance $$ ☐ Low Maintenance $

Returned Concrete Windrow

Advantages

- **Recycles excess concrete into a beneficial product**. Typically, excess concrete hardens within a few hours and is then processed by a crushing and screening plant for sale as recycled aggregate base. By using returned excess concrete to create road base, an excess product is diverted from the landfill and is converted to beneficial reuse.
- **Conservation of Natural Resources**. Reuse/recycle of returned excess concrete as road base offsets the need for mined or quarried material.
- **Placement on existing surfaces**. The windrowing area can be designed for low maintenance and staged in or adjacent to an existing concrete rubble recycle area, using compacted-soil or concrete pads.
- **Capital Cost.** Capital costs are site-specific and can vary significantly depending on such considerations as 1) existing site surfaces, 2) available space, 3) location, 4) climate, etc.

Limitations

- **Siting and Design Requirements.** The size of the area used for the collection of returned excess concrete must have truck access and be able to withstand the type of traffic it will receive during placement and additional handling of the returned concrete. Considerations for prevention of stormwater off-site run-off and run-on may necessitate diversion BMPs, such as curbs, swales, berms, and basins.

Returned Concrete Windrow

Uses/Engineering/Design

- To facilitate the proper handling of the returned excess concrete, it should be poured from the ready-mix concrete truck into a long narrow pile, commonly called a windrow.
- The windrowed concrete should be gathered and placed into the returned concrete rubble pile or shipped off-site in a timely manner.

Prohibited Materials/Activities

- Returned concrete with free water or process water from truck/chute rinsing activities should not be placed on an unpaved surface and should be placed in a concrete lined basin or similar control structure which prevents impacts to groundwater.
    - Some operators integrate chute rinsing with a paved windrow pad capturing and directing water to process water system.

Implementation/Maintenance

The windrowed concrete area should be visually monitored regularly to ensure BMP requirements are being met.

3.11 Rock Out of Mixer Truck Drums

Rock-Out of Mixer Truck Drums

Description

Rocking-out is a procedure used for cleaning the insides of mixer-truck drums using no water. Aggregate or sand is added to the drum and rotated to clean concrete residue from the drum. The aggregate/residue mixture is discharged and recycled.

At this time, this is not a widespread practice in the State of California.

Applicability	Targeted Constituents	Estimated Costs
☒ All Facilities	⊕ Suspended Solids	☐ High Capital $$$
☐ New Facilities	⊕ Dissolved Solids – Metals	☐ Moderate Capital $$
☐ Facilities Undergoing Significant Renovation	∅ Petroleum Hydrocarbons	☒ Low Capital $
☐ Facilities Undergoing Minor Site Improvements	⊕ pH Changes	☐ High Maintenance $$$
		☐ Moderate Maintenance $$
		☒ Low Maintenance $

Rock-Out of Mixer Truck Drums

Advantages

- **Water Conservation.** Virtually eliminating water uses for mixer truck drum washout will conserve approximately 300 gallons of water per truck.
- **Process Water Basin Management.** Eliminating drum washout into the process water basin helps to avoid overtaxing the system with excess water and concrete paste. Based on the amount of water used for washout listed above, a facility with 50 trucks could reduce the amount of water discharged into the process water basin by approximately 15,000 gallons per day. In addition, this practice will reduce the frequency of cleaning concrete paste out of the process water basin and reduce the operational costs associated with handling and disposal of paste. A new facility may also be able to design and construct a smaller process water basin system if they commit to the rock-out procedure.
- **Reduced Drum Chipping.** Some reports indicate that the rock-out procedure does a better job of "scrubbing" the drum clean than does water, thus reducing the amount of drum chipping needed.

Limitations

- **Space Requirements.** Windrowing the coarse aggregate for recycling into base material will utilize a significant amount of space at the facility. Blending the coarse aggregate back into the virgin feedstock will utilize much less space as there only needs to be room to hold coarse aggregate generated during the previous operating day.
- **Increased Hauling.** Facilities that are not co-located with a recycle plant or do not have enough available space to periodically bring in a portable recycle plant will be required to haul the coarse aggregate off-site. The cost of the haul could be off-set by backhauling virgin aggregates if the source facility also has a recycling operation.
- **Rock vs. Gravel.** It has been reported that gravels are significantly less effective at rock-out cleaning of truck drums. Crushed rock is the material of choice.

Rock-Out of Mixer Truck Drums

Uses/Engineering/Design

- **End of Day.** After the final load delivery of the day (or after waiting at the jobsite for an extended period) for each truck, all returned concrete is windrowed or run through a reclaimer. Approximately 1,000 pounds of coarse aggregate is added to the drum and the drum is rotated at a relatively high rate to clean the inner portions of the drum. If the plant is co-located with an aggregate plant, 1,000 pounds of off-spec coarse aggregate can be an acceptable material for use in cleaning the drum. The material is discharged for later recycling. The chutes should not be rinsed in this area and should be rinsed into a reclaimer or process water collection basin. This discharged material can be used to produce recycled aggregate base.

- Alternatively, the material can be stockpiled and blended back into the coarse aggregate feedstock the next day. In this case, the loader operator must be attentive to blend the material into the virgin feedstock in small amounts at any one time to avoid having excess drum residue material into the batch. The loader operator may also need to keep the stockpile agitated to avoid the material from getting overly hardened.

- **Change of Colors.** In the event that a mixer truck is transporting concrete that is a different color than the previous load, the procedure above could be followed, but instead of using 1,000 pounds of coarse aggregate, 2,000 pounds of sand is used to replace the coarse aggregate.

Implementation/Maintenance

- Minimal maintenance is required.

Cost

- **Low to Moderate.** Costs for this procedure are generally off-set by reduced water consumption, reduced water pumping, reduced paste management, and possible reduced chipping. Hauling coarse aggregate off-site will increase the costs considerably.

3.12 Schmutz Drying Pad/Basin Cleanout

Schmütz Drying Pad

Description

A Schmütz Drying Pad refers to a designated area where solids removed from a site's process water basins can be safely stored to drain for later re-use or disposal. The area must be lined with concrete and be sloped or bermed so that any run-off water will be contained within the area or channeled back to the process water basin.

Applicability	Targeted Constituents	Estimated Costs
☐ All Facilities ☐ New Facilities ☒ Facilities Undergoing Significant Renovation ☒ Facilities Undergoing Minor Site Improvements	⊕ Suspended Solids ⊕ Dissolved Solids – Metals ∅ Petroleum Hydrocarbons ∅ pH Changes (Note: This BMP does not effect pH directly, however, a pH reduction circuit can be appended to this system)	☐ High Capital $$$ ☒ Moderate Capital $$ ☐ Low Capital $ ☐ High Maintenance $$$ ☐ Moderate Maintenance $$ ☒ Low Maintenance $

Schmütz Drying Pad

Advantages

- **Can Be Retrofitted Onto an Existing System.** A Schmütz Drying Pad can be retrofitted onto any existing process water containment system. The best results will be achieved when used in conjunction with a windrowing pad and a weired process water basin. However, older systems with deep process water basins can be improved with the addition of a contained drying pad for excavated solids.
- **Moderate Maintenance.** The amount of maintenance required for a Schmütz Drying Pad will greatly depend on the type of process water system that it services, but regardless of the type of system, the cost of maintaining a Schmutz Drying Pad will be minor to moderate.

Limitations

- **Must Be Well Managed.** Because of the fine-grained nature and water content of the material, considerable time is required to dry/dewater. If wet solids are not carefully handled, housekeeping challenges will arise, and the management of the drying solids will become more complicated.

Uses/Engineering/Design.

- **Design.** The design of the Schmütz Drying Pad requires the following careful considerations:
    - The pad can be subdivided, so some solids can dry and dewater, and freshly excavated solids can be placed into the second area, if needed.
    - The pad and associated walls should be designed to hold the maximum expected quantity of excavated solids.
    - The pad should be located and sloped so all runoff is captured and contained, preferably into the process water basin.
- No professional engineering is likely needed. However, as discussed above, the ability to remove and properly handle returned concrete from the truck prior to washout and properly contain the resulting washout water must be in place. These systems will require site specific engineering and design.

Schmütz Drying Pad

- **Process Flow Considerations.** A Schmütz Drying Pad, as well as a windrow area, and a weired process water basin will require the least management and will function most efficiently if they are located in close proximity to each other and function as a unit.

Implementation/Maintenance

- Maintenance for a Schmutz Drying Pad is dependent on the type of water system that it services. A weired process water basin system with windrowing pad and minimal washout will produce a relatively small amount of waste solids, and require less maintenance. However, a deep process water basin that receives a large amount of solids between cleanings will generate a large amount of fine grained "paste." This will require a larger area for the Schmütz Drying Pad, and a longer time for the fine material to drain and dry.

Cost

- **Capital Costs.** Installation cost of a Schmütz Drying Pad will vary. Simple systems may consist of a dedicated portion of an existing lay-down pad. More elaborate, and thusmore costly, systems may consist of a concrete pad with "bin block" walls. Most costly will be a reinforced pad and formed walls.
- **Maintenance Costs.** Maintenance costs for a Schmütz Drying Pad are minimal to moderate, consisting of normal housekeeping and repair.

Schmütz Drying Pad

Single bay Schmütz drying pad built on a concrete pad using "Bin Blocks"

Schmütz Drying Pad

Two-bay Schmütz drying pad, one bay used for color washout only.

3.13 Storm Water Utilization

Stormwater Utilization

Description

Many concrete producers have means to capture stormwater and use it for a variety of applications in the production of ready mixed concrete. Water other than municipal/well can be used as mix water in ready mixed concrete but the producer must follow procedures in ASTM C1602 in order to ensure its quality meets standardized limits.

Applicability	Targeted Constituents	Estimated Costs
☐ All Facilities ☒ New Facilities ☒ Facilities Undergoing Significant Renovation ☐ Facilities Undergoing Minor Site Improvements	⊕ Suspended Solids ⊕ Dissolved Solids – Metals ⊕ Petroleum Hydrocarbons ∅ pH Changes	☒ High Capital $$$ ☐ Moderate Capital $$ ☐ Low Capital $ ☐ High Maintenance $$$ ☐ Moderate Maintenance $$ ☒ Low Maintenance $

Stormwater Utilization

Advantages

- **Water Conservation/Costs.** Using stormwater from retention areas reduces or eliminates purchased water and reduces pumping costs from deep water wells. The use of stormwater also reduces drawdown from groundwater aquifers and/or conserves water treated for human consumption.
- **Stormwater Run-Off Compliance.** Sediments and other materials transported by stormwater should not be discharged from areas where stormwater is collected for use. Stormwater from process water areas should be collected in basins or other containment structures. In some cases, all stormwater from the entire facility can be collected and never discharged, virtually eliminating liabilities associated with the discharge of stormwater.
- **Reduces the Potential Off-Site Discharges of Comingled Water.** Containing stormwater for subsequent use may also help reduce the potential for the discharge of stormwater that has comingled with process water.
- **Passive System.** While the actual use of stormwater is not a passive operation, collection of stormwater for use typically is. If properly designed, the collection of stormwater for subsequent use can occur passively through rainy cycles and seasons – continuous human oversight may not be needed.
- **Low Maintenance.** Depending on the containment system used, the maintenance of a stormwater collection system can be low. Pumps and piping will need to be periodically maintained. Sediment from the containment system may need to be periodically removed.

Limitations

- **Capital Costs.** Containment structures to collect and store stormwater for subsequent use can be expensive to construct. These structures may include concrete lined pond(s), earthen pond(s), and/or tank(s), etc. All structures require capital expenditure and these costs may be substantial. Costs will vary depending on the size a facility, annual rainfall, and whether it is a new or existing facility.

- **Potential Groundwater Impacts.** Stormwater may contain constituents that represent a threat to groundwater quality. If the collection and storage structures are not lined, analyses may be required to ensure that the potential for impacts to groundwater are negligible.
- **Size and Siting Requirements.** The size of the system used for the collection of stormwater can be relatively large and many facilities may not have adequate space available. Existing facilities may not be properly graded to enable collection at an available location of the facility. Re-grading could involve removing concrete, asphalt, and possible temporary removal of the plant itself. An engineered evaluation is needed in order to ensure that the containment structure is properly sized for the area of the facility that drains into it. The square footage of the stormwater runoff area, periodic rainfall maxima, and the porosity of the area draining to the collection system all require evaluation by an experienced professional. The evaluation must consider the fact that minimal water will be used by the plant during the "wet" season while stormwater is being accumulated in the containment structure(s).
- **Quality Control.** As mentioned above, the water should be analyzed by checking for any impurities that may adversely affect concrete quality in accordance with ASTM C1602.

Uses/Engineering/Design

- Stormwater may be used for various plant processes, including site dust control; washout, washdown, or rinsing activities; irrigation; etc.
- When evaluating the potential use of stormwater as a source of process water for concrete batch water, samples must be taken and analyzed to check for any impurities that may adversely affect concrete quality, in accordance with ASTM C1602.
- Impurities potentially present in stormwater that could diminish concrete quality must be corrected.
- In some cases, blending stormwater with municipal/well water may be an excellent option for use as concrete batch water. If treatment costs

are high for use in concrete batching, it may be more cost effective to use stormwater for haul road dust suppression or as a supply for truck wash/rinse activities, and restrict batching to municipal/well water. Producers should also consider the resources needed to use stormwater such as pumps, motors, piping, sumps, and fencing for stormwater retention areas. The facility operator should also consider what options should be taken during winter months of operations when pipes may freeze and stormwater use can be more difficult.

Implementation/Maintenance

See discussion on sampling and treatment above.

Cost

3.14 Training

Training

Description

Proper training and education of employees is one of the most important aspects of the facility's effective process water management.

It is important that each employee involved with process water management understands the management objectives and requirements and follows all relevant BMPs.

Applicability	Targeted Constituents	Estimated Costs
☒ All Facilities ☐ New Facilities ☐ Facilities Undergoing Significant Renovation ☐ Facilities Undergoing Minor Site Improvements	⊕ Suspended Solids ⊕ Dissolved Solids – Metals ⊕ Petroleum Hydrocarbons ⊕ pH Changes	☐ High Capital $$$ ☐ Moderate Capital $$ ☒ Low Capital $ ☐ High Maintenance $$$ ☐ Moderate Maintenance $$ ☒ Low Maintenance $

Advantages

- Training minimizes environmental impacts, and satisfies regulatory requirements.
- Training enhances productivity.
- Training helps ensure regulatory compliance.
- Training helps control compliance and maintenance costs.

Limitations

- There are no limitations to effective and thorough training.

Uses/Engineering/Design

Training of employees should be conducted and records of all training should be maintained and be readily available, according to applicable permit requirements. The training log should include the type, time, location, training topics, and employees' names. Process water training may be combined with other trainings, such as Stormwater training, for cost effectiveness.

- **Tier 1 Training** should be a comprehensive training that occurs when a new employee is hired. Tier 1 Training should be refreshed periodically and specific to job duty. This training should target managers and employees who actively manage and are responsible for the operation and maintenance of the process water management systems.
  - Tier 1 Training should include the following:
    - A general synopsis of Federal, State, and local regulatory requirements governing the management of process water and stormwater, including a plant's specific permit requirements.
    - A general understanding of concrete process water and its potential impacts to surface and ground water.
    - A site-specific understanding of the process water and storm water areas of the site.
    - An understanding of the BMPs that have been chosen and implemented at the facility.

        - An understanding of the choice of other potential BMPs that may be required in order to adapt to changing operational, site, environmental, or climatic conditions.
        - An understanding of inspection and maintenance requirements.
        - An understanding permit requirements.
        - An understanding of emergency-response procedures.

- **Tier 2 Training** should target ready mix concrete truck drivers and plant/fleet maintenance personnel who conduct operational activities at the site, but are not responsible for the operation and maintenance of the process water and storm water management systems. Tier 2 training should be conducted for all employees new to a particular plant or facility and be refreshed on an annual basis.
    - Tier 2 training should include the following:
        - A general understanding of the descriptions of and differences between process water and storm water.
        - A discussion of pond level characteristics such as the minimum required free board or maximum water height, and whom to contact if these levels are approached.
        - Instruction regarding the beneficial effect of water conservation, and the detrimental effects of water overuse.
        - Instruction on the use of piping and water control shut off valves.
        - What to do if any out-of-compliance situation is observed. An understanding of emergency-response procedures.

Implementation/Maintenance

The training should be implemented in accordance with company policy and all documents and training records must be retained in accordance with the facilities permit.

Cost

- Training costs are usually limited to the costs of preparing materials, and to the straight-time and over-time wages.

3.15 Process Water Management – Washout and other Ponds

Process Water Management – Process Water Basins and Other Ponds

Description

Basins, ponds and water containment systems that exist on Ready Mix Concrete Facilities vary in design. Managing the washout from washing out truck drums and containing other process waters directed to containment systems from around the facility are critical to preventing discharge of contaminated waters.

Basins, ponds, weirs, and vaults at concrete facilities are the heart of the operation serving as the center of a system which captures process water and concrete slurries and return concrete, separates the solids and reuses the water to make new concrete.

Applicability	Targeted Constituents	Estimated Costs
☐ All Facilities	⊕ Suspended Solids	☒ High Capital $$$
☒ New Facilities	⊕ Dissolved Solids – Metals	☒ Moderate Capital $$
☒ Facilities Undergoing Significant Renovation	⊕ Petroleum Hydrocarbons	☐ Low Capital $
☐ Facilities Undergoing Minor Site Improvements	⊕ pH Changes – depending on discharge permit conditions	☐ High Maintenance $$$
		☒ Moderate Maintenance $$
		☐ Low Maintenance $

Process Water Management – Process Water Basins and Other Ponds

The function of the washout and process water basin system is stable across facilities: however, the designs of individual systems may vary due to space constraints and the needs of each individual site. Generally, the primary "basin" is a weired process water structure as discussed in Section 3.16. Facilities with less land space available may have a single vaulted drive over wash rack system, as in the photo. These primary process water basins may not be sufficient to manage a facility's full process water volume. The primary basins may be connected via piping/lined channels and gravity to a secondary pond whose primary design is containment of process water within which the solids have already settled and pending reuse within the concrete plant. Please note that the industry may describe process water basins as washout basins/settling ponds/settling basins or other interchangeable terms.

Construction sites may utilize a third kind of temporary containment pond to support concrete grinding activities which create a slurry of cured concrete and water. These ponds primarily serve as evaporative ponds and are generally lined with artificial liners at least 40 mil (1.0 mm) thick. Once the water has sufficiently evaporated, the dry material will be separated and either mixed with larger concrete debris as part of recycled aggregate base materials or disposed of at an appropriately permitted disposal site.

Most permanent facilities will choose to utilize a concrete lined pond for durability, maintenance, and cost reasons because they produce the concrete. However, shorter lived facilities and temporary washout ponds or temporary ponds will often choose a synthetic liner instead. In construction and temporary scenarios, portable washout bins are also utilized.

Process Water Basins should be designed as follows,

- Be designed by a licensed professional engineer using good engineering practices, with consideration given to stability of the pond structure and permeability.
- Be designed and operated with enough freeboard to adequately store process water and stormwater runoff from areas that drain to the pond.

Process Water Management – Process Water Basins and Other Ponds

- Concrete liner shall generally be a minimum of 6” thickness in process water basin area’s subject to mechanized cleanout, and may often be thicker based upon engineering.
- If the pond will accommodate vehicles (e.g., for cleanout activities) the concrete will be stabilized with reinforcing steel bars for the anticipated traffic load.
- Secondary basins/ponds not subject to mechanized activities may be constructed with shotcrete in accordance with general industry practice.
- Synthetic Liners should be used in accordance with manufacturer’s directions and project engineering design, where utilized.
- Minor cracking in concrete is normal. Significant cracks or defects shall be identified and repaired during cleanout activities.

Advantages

- Properly designed and constructed process water basins and ponds create a comprehensive process water management system
- Prevent Discharge of Pollutants
- Recycle/Reuse Water
- Durable

Limitations

- Space Available
- High Cost

Uses/Engineering/Design

- When engineering a process water basin system, several aspects of the design must be considered.
  - Sizing. An engineered evaluation is needed in order to ensure that the basin is properly sized for the area of the facility that drains into it. The square footage of the process water runoff area, periodic rainfall maxima, the proximity of the collection area to the basins and the traffic patterns within the plant all require careful study and evaluation by an experienced professional.

Process Water Management – Process Water Basins and Other Ponds

- Minimal Structural Concerns. Site soil conditions must be considered when designing the concrete lining for the process water basin. Structural integrity must be maintained under maximum loads expected from front end loader and mixer truck traffic.
- Flow. Gravity flow to the weired process water basins has been shown to be the preferred mode of transport of excess process water, whether via concrete swales or grated ditches. However, particularly during retrofit installations, it may be necessary to pump the excess process water to the basin.

Implementation and Maintenance

- Monitor freeboard and manage to prevent discharge.
- Inspect for and document repairs of significant cracks during clean out activities.
- Train truck drivers and equipment operators on use of washout pond system.
- Settled wastewater may be recycled by the plant in the following ways:
  - Recycled back into the concrete production operation.
  - Recycled back into the washout system.

Cost

Medium to High

3.16 Weired Process Water Basin

Weired Process Water Basins WB-02

Description

A weired process water basin system consists of a series of concrete lined settlement basins designed to collect and treat process water from truck and plant processes, allowing for process water reuse. The weired process water basin directs the water through a series of sequential chambers, separated by weirs.

The decant over the weirs, the reduced flow velocity, and the increased travel distance allows suspended solids to drop out of the water column to the bottom of each weir basin, where they can be removed via regular cleaning using front end loader. The water collected in the final weir basin can then be pumped directly back to the plant for immediate reuse, transferred into in-ground or above-ground storage tanks for later use, or directed to a storage pond for later use.

Applicability	Targeted Constituents	Estimated Costs
☐ All Facilities ☒ New Facilities ☒ Facilities Undergoing Significant Renovation ☐ Facilities Undergoing Minor Site Improvements	⊕ Suspended Solids ∅ Dissolved Solids – Metals ⊕ Petroleum Hydrocarbons ∅ pH Changes	☒ High Capital $$$ ☐ Moderate Capital $$ ☐ Low Capital $ ☐ High Maintenance $$$ ☒ Moderate Maintenance $$

Advantages

- **Semi Passive System.** A weired process water basin system is a semi-passive treatment method to allow for the reuse of excess process water. If properly designed and maintained, the system will collect and treat excess process water with only periodic human oversight.
- **Simple Treatment Process.** A weired process water basin can be designed with no moving parts, although most systems utilize one or more pumps. The main operational forces that drive the system are gravity and time.
- **Moderate Maintenance.** If properly designed, a weired process water basin requires only periodic maintenance. The first sequential weir basin should be cleaned of accumulated sediment on a daily basis, usually prior to plant start-up. This allows for additional settling time during the non-operation hours of the day. The remaining weir basins will require less frequent cleaning. A site-specific cleaning schedule should be determined to optimize operating efficiently.
- **Amenable to Customization.** The basic weir basin design can be easily adapted to site-specific conditions or issues. This can be achieved by increasing, or decreasing, the number of weir basins or by the addition of one or several optional components. Examples of add on components are:
  - Integral Wash-Out Concrete Pad. An integrated wash out pad adjacent to the first weir basin sloped so that all water placed on the wash out pad will flow to the first weir. This allows mixer drums to be rinsed with recycled water taken from the last weir and returned to the first weir. This increases wash out efficiency as long as consideration is given to the following: all possible concrete solids must be removed from the drum prior to wash out, the area of the wash out pad must be included in the process water runoff area. (See Engineering, below.)
  - Inter-weir Filtration. A number of highly efficient, in-channel, filtration products are now available on the market. These are sometimes referred to as "bristle or brush" filters and can be fitted into the inter-basin weir openings to increase physical filtration

during treatment of the excess process water. These filters can either be incorporated into the original design, or retrofitted into existing systems.

- Flocculation. To increase the settlement of fine particulate matter, various flocculent chemicals can be introduced into the system. This can be achieved by metered liquid chemical injection, manual broadcasting of dry powder on the water surface or suspending flocculent gel “logs” in the inter-basin weir openings.
- pH Adjustment. If it is necessary to adjust the finish water pH for reuse or disposal (for example, discharge to a sanitary sewer or POTW) a pH adjustment circuit can be added to treat, all or a portion of, the finish water leaving the system. This can be achieved by either acid injection or a CO_2 bubbler system. In either case, consideration must be given to proper mixing technologies and precipitate disposal.
- Finish Water Storage. It is often the case, particularly during wet weather and times of fluctuating customer demand, that more finish water is generated that can be immediately used by plant operations. This is exacerbated when it was not possible to minimize the process water runoff area during initial design. To remedy this issue, finish water storage can be added either as part of the initial design, or retrofitted to improve an existing system.

Limitations

- **Capital Costs.** A weired process water basin system is expensive to construct. In addition, if siting restrictions result in unfavorable placement, additional costs will be incurred from the construction and installation of swales, ditches, piping and pumps. These additional equipment and structures will also increase operation and maintenance costs over the life of the basin system.
- **Wet Weather Limitations.** During wet weather, rain fall within the process water runoff area will be captured by the weired process water basin system. If insufficient storage is provided, or the area of process water runoff is excessive, the basin system can be inundated and overtopped.

Uses/Engineering/Design

- When engineering a weired process water basin system, several aspects of the design must be considered.
  - Sizing. An engineered evaluation is needed in order to ensure that the basin is properly sized for the area of the facility that drains into it. The square footage of the process water runoff area, periodic rainfall maxima, the proximity of the collection area to the basins and the traffic patterns within the plant all require careful study and evaluation by an experienced professional.
  - Minimal Structural Concerns. Site soil conditions must be taken into account when designing the concrete lining for the weired process water basin. Structural integrity must be maintained under maximum loads expected from front end loader and mixer truck traffic.
  - Flow. Gravity flow to the weired process water basins has been shown to be the preferred mode of transport of excess process water, whether via concrete swales or grated ditches. However, particularly during retrofit installations, it may be necessary to pump the excess process water to the basin. (See Siting Considerations below.)
  - Ease of Cleanout. Thought should be given to ease of basin cleanout and the equipment used. Depth and width of the basins should be fitted to the front end loader used for cleanout.
    - The depth of the wetted surface in each basin should never be greater than the center line of the wheel radius of the loader to be used for basin cleanout. Greater basin depths will result in increased maintenance and possible damage to the loader.
    - The width of each basin should be kept to a minimum to allow loader access. Usually the basin should be about one foot greater in width than the width of the loader bucket. This greatly reduces the amount of water and sediment that will be flushed around the loader bucket during cleanout.
    - When laying out the placement of the of the basin system one should consider the front end loader access for basin cleanout

and the path of the loader to the storage area where the removed sediment will be placed.

- **Siting Considerations.** In general, the key to success of a weired process water basin system is to keep the area of excess process water generation, and therefore, collection to a minimum. To achieve this, it is best to site the basin system imminently adjacent to the plant with all appurtenant excess process water generating processes in close proximity (slump racks, wash out stands, etc.) This is best accomplished at new facilities where the basin system can be engineered into the preconstruction design. However, when a weired process water basin system is retrofitted into an existing facility, the current site configuration grading and underground utilities may require that the basin system is placed some distance from the plant and other excess process water generating operations. This often results in additional process water runoff area that must be considered when designing for rainfall maxima and finish water storage. Likewise, means of conveyance to the basin from the other areas of the facility need to be considered – whether via overland flow through swales, or through pipes or trenches.
- **Space Requirements.** The base area for a simple four chambered weired process water basin system is about 50 by 50 feet. However, the addition of sloped aprons, feeder swales, adjacent slump and wash out racks can increase this minimal area several fold.

Implementation/Maintenance

- A properly engineered weired process water basin requires only periodic maintenance.
- The first sequential weir basin should be cleaned of accumulated sediment on a daily basis, usually prior to plant start-up. This allows for additional settling time during the non-operation hours of the day.
- The remaining weir basins will require less frequent cleaning.
- A site specific cleaning schedule should be determined to optimize operating efficiently.

Cost

- **Capital Costs.** The design and installation of weired process water basins is high, commonly exceeding $150,000 for a basic system. Because of the high capital cost it is most appropriate for new facilities and facilities undergoing major renovation. Cost savings can be realized with the design of a gravity flow system in close proximity to the batch plant. This reduces pump installation costs and auxiliary concrete work.
- **Maintenance Costs.** Maintenance cost for weired process water basins is moderate, consisting mostly of housekeeping and minor repairs. A design that relies on numerous pumps and piping runs will require substantially more maintenance than a simple gravity flow system.

APPENDIX 1

GLOSSARY

Glossary

100-Year Storm	A storm intensity that has a 1-percent probability of occurring. For greater definition of the intensity of the storm, the duration of the storm needs to be specified, e.g., a 1-hour storm, or a 24-hour storm.
Adsorption	A process in which soluble substances are attracted to and held at the surface of soil or other particles.
Acidity & Alkalinity	Relative terms for the amount of hydrogen cation (H^+) or hydroxyl anion (OH^-) present in an aqueous solution, respectively.
Aggregate, Coarse	Any of several types of gravel or rock. Coarse aggregate is typically retained on (does not pass through) a #4 sieve (0.187 inches).
Aggregate, Fine	Any of several types of sand that would pass a #4 sieve (0.187 inches).
Aquifer	A geologic formation or stratum that contains and is saturated with water.
Block Forms	Any of several types of forms used to cast blocks, rip-rap, K-rail, sound walls, parking lot curbs using returned concrete. These items are not engineered pre-cast concrete products.
Cementitious Material	Any of the various forms of Portland cement, various types of flyash, various types of ground granulated blast furnace slag, or various types of mineral powders.
Conductivity	The quality or capability of transmitting electricity; usually measured in aqueous solutions as electrical conductivity (EC). Increasing conductivity of water typically correlates with the increasing presence of dissolved solids, particularly cations and anions.
Fixation	Physical and/or chemical mechanisms in the soil that act to retain water pollutants, including adsorption, chemical precipitation, and ion exchange.

Groundwater	The body of water that is retained in the saturated zone. Groundwater frequently moves by hydraulic gradient.
Groundwater Table	The free surface elevation of the groundwater; this level will rise and fall with additions or withdrawals.
Industrial Stormwater Discharge	The discharge from any conveyance that is used for collecting and conveying storm water and that is directly related to manufacturing, processing, or raw materials storage areas at an industrial plant (reference Industrial Stormwater Permit).
Infiltration	The passage of water from above the soil surface into the vadose (unsaturated) zone of the subsurface.
Irrigation	The application of water to the land to meet the growth needs of plants.
Mineralization	The conversion of a compound from an organic form to an inorganic form as a result of microbial activity.
Permeability	The ability of a substance (soil) to allow passage of water.
Process Water Footprint	Consists of all plant area encompassing cementitious processes, including ready mix concrete batching and loadout, and the process water management system.
Process Water System	Consists of all infrastructure and equipment for the collection, storage, reuse, and possible treatment of process water. Process water systems infrastructure and equipment may include swales, ditches, culverts, pipes, basins, pumps, and tanks.
Throughput	A term frequently used in the ready mix concrete industry to describe the volume of concrete manufactured over any given period of time, e.g., 180 cubic yards per hour. Some regulatory agencies use the term "throughput" to also describe the mass of any given material utilized in plant processes over any given period of time, e.g., 875 tons of coarse aggregate per day.
Water, Effluent	Water that exits the process water system of a facility, whether as a permanent part of the ready mix concrete matrix, as a sanitary sewer discharge, or as evaporation.

Water, Influent	Water that enters the process water system of a facility, whether from municipal supply, well, or stormwater runon.
Water, Process	Any water that has come into contact with plant processes and/or cementitious materials. Please see also the definition for Industrial Stormwater.
Windrow	The practice of placing unused concrete into long, narrow piles. The windrows are easily broken up by a loader for beneficial reuse.

Acronyms

BMP	Best Management Practice, consisting of one or more of the following, which is (are) implemented to mitigate the potential for the contamination of stormwater: evaluations, infrastructure enhancements, process enhancements, or work patterns.
LEED	Leadership in Energy and Environmental Design, an internationally recognized green building certification system.
mg/l	milligrams per liter. This is a typical measurement of potential pollutant concentration in water. One milligram is the mass of one-millionth of a liter of water, so this measurement is sometimes referred to as parts per million.
mmho/cm	millimhos per centimeter. These units are commonly used to report the electrical conductivity of a sample of water.
pH	A measure of the absolute concentration of hydrogen ion (H^+) in water. pH is the negative of the base 10 logarithm of the hydrogen ion concentration in moles per liter.
PM	Particulate Matter
POTW	Publicly Operated Treatment Works
SWPPP	Stormwater Pollution Prevention Plan

TDS	Total Dissolved Solids. This is a measure of pollutants that are soluble in water. Dissolved solids may include metal and non-metal ions and certain types of organic compounds.
TOC	Total Organic Carbon. This is a measure of organic pollutants that are varyingly soluble in water. The measurement may also include immiscible organic compounds floating on the surface of the water.
TSS	Total Suspended Solids. This is a measure of pollutants that are not soluble in water, and may remain suspended in water. Suspended solids include fine particles of aggregate and cementitious material.
µg/l	micrograms per liter. This is a typical measurement of potential pollutant concentration in water. One microgram is the mass of one-billionth of a liter of water, so this measurement is sometimes referred to as parts per billion.

APPENDIX 2

ARTICLE “RECYCLED WATER IN READY MIX CONCRETE OPERATIONS”

Recycled Water in Ready Mixed Concrete Operations

The following article presents the findings of the effects of using reclaimed/recycled process water in ready mix concrete batch plant operations and is reprinted with permission from the NRMCA.

Recycled Water in Ready Mixed Concrete Operations

By Colin Lobo, Ph.D., P.E. and Gary M. Mullings

Introduction

Process and storm water management at ready mixed concrete operations is a growing issue for the industry. As regulations and enforcement governing discharge from plant sites evolve, the option of reusing these sources of water will become a necessity, thus moving the industry towards zero-discharge facilities. It is important that positive terminology is used in describing the source of water and that the customer is informed of its use in a positive manner. In this article, the term *recycled* water will be used for mixer wash water, storm water or *gray water*. Concrete producers face the dichotomy whereby their customers are generally resistant to allowing the use of recycled water in their concrete while producers are forced to move in that direction because it's the environmentally responsible thing to do and there is a cost, sometimes un-quantified, associated with its disposal. It's true that when moving towards zero discharge the producer has to make an investment on equipment, people and training, but in the relatively short term this investments will be recovered in a successful application. Producers who are leaders in environmental management initiatives have demonstrated this fact, without including cost of compliance and enforcement penalties.

The initial need for using recycled water in concrete came from California in the early 1970s due to evolving environmental regulations. NRMCA members collected data of water from typical sedimentation pits and the effects on concrete when this water was used as mixing water. Based on these evaluations, criteria were developed and in 1978 ASTM C 94, *Specification for Ready Mixed Concrete* was revised to permit the use of wash water as mixing water in concrete. State highway agencies for the most part still do not allow its use or if they do, their requirements are more conservative that C 94. The criteria or requirements for wash water in C 94 have not changed since they were originally incorporated in the standard. In the 70s, producers in California were looking for some relief to use some of their recycled water and reduce the quality of effluent from their production facilities and were not really striving for zero-discharge facilities. They retained the problem of cleaning out debris from sedimentation pits, handling it and disposing it in landfills. The industry's needs have changed and so should the standard to allow an increased use of wash water, while protecting the consumer. Current technology better facilitates the collection of process and storm water with the associated solids, water treatment, and automated measurement and batching.

ASTM C 94 has criteria for wash water that can be invoked at the option of the purchaser. While these are optional requirements, the uninitiated producer, relative to use of recycled water, should try to remain within these limits for any structural concrete or slab application. The requirements apply to the total mixing water in concrete and are essentially limits on the water chemistry for alkalis, sulfates and chlorides for reasons related to concrete durability. The other limiting criterion is the amount of total solids, which is limited to 50,000 parts per million (ppm) or 5% by mass. This amounts to about 15 lb. of solids in 1 cubic yard of a typical concrete mixture. Does it matter if the solids added to the mix from recycled water exceed this limit? It depends on the concrete ingredients, characteristics of the recycled water, time of year, and everything else that one could think of. The important issue is that the concrete should meet the requirements of the job and the purchaser does not observe or perceive any diminished quality or batch-to-batch variation. It takes just one bad story to generate a negative perception and essentially kill any initiative to move forward on this important issue. ASTM committees have been deliberating for the last several years on revising the provisions for mixing water and while the consensus process can be frustrating, it hopefully achieves a better standard that satisfies the producers and their customer.

This is a brief report of portions of the research conducted at the NRMCA

Recycled Water in Ready Mixed Concrete Operations

Alfred H. Smith Research Laboratory to answer some questions on reusing recycled water in concrete. The study was intended to simulate a practical situation where a producer has an environmental management system that includes a returned concrete reclaimer that generates recycled water slurry. The slurry is kept agitated in tanks and is used in a controlled manner as a portion or all of the batch water in concrete mixtures. An important point to note is that the characteristics of the slurry in this tank will be quite variable as water is removed and added to it from truck wash out during any production day. Figure 1 illustrates the variation of solids content with time from an actual recycled water holding tank. Adding this variable product without control is sure to cause batch-to-batch variations of concrete properties. It is imperative that the producer has a system in place that recognizes this variability and adjusts for it so that the customer does not see differences in concrete performance properties in subsequent loads of concrete.

The first phase of the study also includes a situation where a producer might use relatively clear water from a sedimentation pit after the solids have settled out. The reader is advised that the data and trends are very specific to the materials and conditions used in this study.

Procedures

The first phase of the NRMCA study was to quantify the basic effects of using recycled water on fresh and hardened concrete properties. A typical air-entrained Portland cement concrete mix design without any admixtures was selected using stock materials from the research laboratory. The design mixture characteristics and proportions are provided in Table 1. The experimental variables used in the study are listed in Table 2. Note that the solids contents of the recycled water, at 30 and 60 lb/yd^3, are at levels that are double and four times the

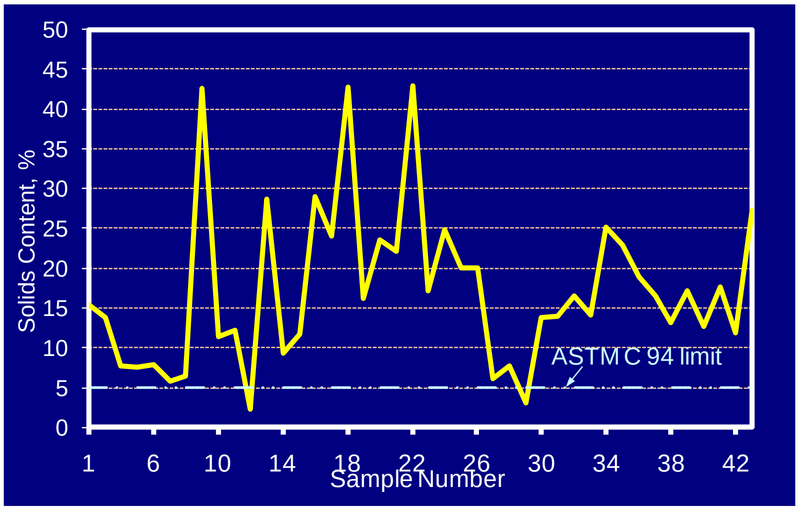


Figure 1 – Variation in Solids Content in Recycled Water

current limit for solids in ASTM C 94. This series was replicated three times for a total of 48 concrete batches.

Table 1 – Design Proportions and Characteristics of Concrete

Portland cement	600 lb/cu.yd
Mixing Water	300 lb/cu.yd.
Natural Sand	1100 lb/cu.yd.
Limestone coarse aggregate, max size 1 inch.	1800 lb/cu.yd.
Air content	4 to 6%
Slump	3 to 5 inches

Table 2 – Experimental variables in Phase I of the Study

Water	• Tap water (Control) • Clarified recycled water • Recycled water at 30 lb solids per cubic yard • Recycled water at 60 lb solids per cubic yard
Age of slurry	• 4 ± 1 hour • 1 day • 3 days • 9 days

APPENDIX 2 Ready Mix Concrete

Recycled Water in Ready Mixed Concrete Operations

Recycled water

Figure 2 – Laboratory Set-up to Maintain Agitated Recycled Water Slurry

A concrete mixture was mixed in a 1 cubic foot mixer, tempered with water to a very high slump and water slurry was decanted over a 150 µm (No. 100 sieve). The water slurry passing the sieve was captured in a 5-gallon bucket and represented the wash water from the mixer. This wash water was kept agitated using a motorized paddle to keep the solids in suspension for the duration of the testing. The water slurry solids content varied from about 40% solids by mass to about 25% towards the end of the series at 9 days as it was periodically diluted to maintain a sufficient volume for the tests. A portion of the recycled water was allowed to stand for about two hours and clear water was siphoned off the top to represent clarified recycled water.

When concrete mixtures were made, samples of the recycled water slurry were obtained and the density was measured by determining the mass of water in a container of known volume. The water slurry sample was then dried to constant mass in a microwave oven to determine the percentage of solids by mass. At least two samples of recycled water were tested in this manner on each day and the average used to establish the water slurry density and solids content. Solids were filtered out from the water slurry to measure the loss on ignition and specific gravity. This information is useful to quantify the progressing degree of hydration of cement in these solids. Loss on ignition is the loss in mass when an oven-dried sample is heated to 750ºC. A portion of the solids were dissolved in acid to determine the insoluble residue. Since cementitious materials dissolve in acid, the insoluble residue represents the fine sand fraction, which was about 10% of the mass of the dry solids.

Concrete batches

On each day, 4 concrete batches with the four types of mixing water listed in the first row of Table 2 were mixed. The concrete batches were nominally 0.75 cubic foot size batches in a 1 cubic foot revolving drum laboratory mixer.

APPENDIX 2 Ready Mix Concrete

Recycled Water in Ready Mixed Concrete Operations

Standard ASTM procedures were used to mix the concrete batches and conduct the fresh and hardened concrete tests. To achieve the target solids contents in the mixing water, recycled water slurry with known solids content was diluted with a calculated quantity of tap water used. Clarified recycled water was used at 100% of the added water in those respective batches.

Testing

Concrete mixtures were mixed to a target slump of 5 inches. After the initial mixing for 8 minutes, slump and density were measured. Air content (gravimetric) was calculated from the measured density. Concrete from these tests was returned to the mixer. The mixer was covered to prevent evaporation and the concrete was periodically agitated and retempered with water as necessary to retain the target 5-inch slump until approximately 30 minutes after the ingredients were batched in the mixer. This was done to simulate a 30-minute delivery time of ready mixed concrete and what might typically occur in practice. It is important to note that the batches were adjusted to achieve a similar target slump and not to a constant water-cement ratio.

After the 30-minute period, the concrete was discharged into a sample container and the mass of discharged concrete was determined so that precise mixture proportions could be calculated.

Fresh concrete tests included slump, temperature and density. Initial setting time was measured by two methods. The first method was in accordance with ASTM C 403 by the penetration resistance on a wet-sieved mortar. On several batches, the heat evolution (or heat signature) of the concrete was measured to estimate the initial setting time. A 4 x 8 inch cast cylinder was placed in an insulated 5-gallon container. A thermocouple embedded in the center of the cylinder was connected to a data logger to obtain the rate of heat evolution of the concrete. A correlation was established between initial set from the C 403 method and a point on the heat signature curve. After some confidence was achieved with this correlation, set time was measured using the heat signature for the batches in the 3rd round of replication.

Specimens for hardened concrete tests from each batch included four 4 x 8 inch cylindrical specimens for compressive strength determination at 7 and 28 days; one 4 x 14 inch cylinder with embedded gage studs for drying shrinkage measurement; one 4 x 14 inch cylinder for freeze-thaw testing; and one 4 x 8-inch cylinder for rapid chloride permeability testing.

Results and Discussion

The results of 3 replicate batches for the same experimental condition was very reproducible and within typical batch-to-batch variation quantified for procedures used at the research laboratory. The average value of 3 replicates of each condition is reported in many cases in the subsequent discussion. Detailed data on calculated concrete mixture proportions, slump, temperature, air content and hardened concrete test results are available and are not reported here for the sake of brevity. Concrete temperatures were in the range of 70 to 75ºF and air contents and slumps were at target levels within the acceptable tolerances.

Water Demand

Figure 3 illustrates the calculated mixing water content for all the batches to achieve and maintain the target 5-inch slump. The chart indicates that the mixing water content for the 9 control batches was quite similar and averaged about 308 lb/yd^3. The chart also indicates the effects of using clarified recycled water and recycled water slurry to incorporate 30 and 60 lb/ solids per yd^3. The recycled water slurry was used at ages of 4 hours, 1 day, 3 days and 9 days

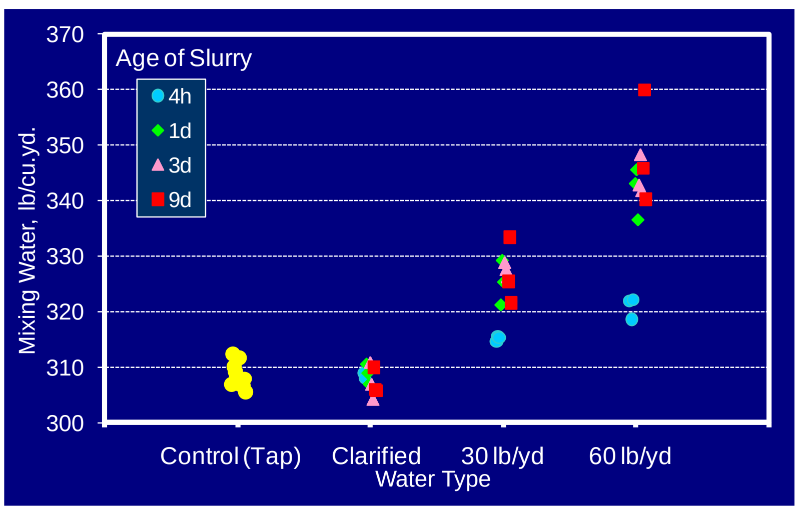


Figure 3 – Mixing water content for Individual Concrete

as indicated in Table 2.

When clarified water was used, the mixing water content was essentially similar to the control batches.

When recycled water slurries were incorporated to achieve the target solids content of 30 and 60 lbs, the mixing water demand to achieve and maintain the target slump increased. The increase is proportional to the amount of solids and the age of the recycled water slurry. With 4-hour old slurries, the increase in mixing water was minimal, but as the slurry is aged past 1 day, a higher water demand is noticeable.

By monitoring the loss on ignition and specific gravity of the slurry solids, it was observed that the continued cement hydration with time causes the solids to get finer and of a lower specific gravity with time. These finer or *fluffier* particles cause the increased water demand. Specific gravity of dried slurry solids varied from around 3.10 at 4 hours to 2.50 and lower at ages 1 day and later.

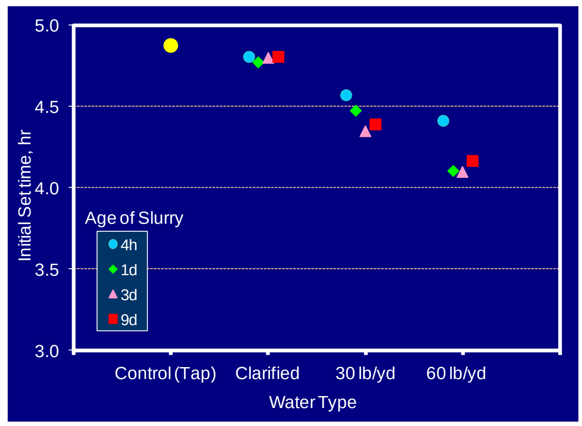


Figure 4: Initial Setting Time of Concrete

Initial Setting Time

Figure 4 illustrates the effects of using recycled water on initial setting time. Values reported are the average of 3 replicate batches for each condition. The setting time of the control is the average of 9 concrete batches.

The initial setting time of the control batch was around 4.9 hours. The setting time of the batches with clarified recycled water was similar to that of the control batches. When recycled water slurry was used, the setting time was accelerated and the faster setting time was proportional to the amount of solids and the age of the water slurry.

The primary problem with reusing recycled water with solids in concrete is the effect on setting time. Hydrated cement and calcium hydroxide (hydrated lime) are known to accelerate setting characteristics. Problems with setting with the use of recycled water slurry will be exacerbated in summer but can possibly be used to advantage in cooler temperatures. These set time data illustrate that the 4-hour old slurry had lesser effect on setting time than slurry that was aged for 1 day or longer. Setting times of concrete with slurries aged for 1 day or longer were essentially similar, possibly because most of the cement solids had hydrated at 1 day.

Compressive Strength

Figure 5 illustrates the 28-day compressive strength of concrete batches representing each experimental condition. The data represents the average of 3 replicate batches for each condition.

The compressive strength data reflects the well-known fact that increased water content in the concrete will cause a reduction in strength. The reduction in strength correlates well to the additional water used in the respective batches. The lower compressive strength of batches containing recycled water with higher solids content could be adjusted for by reducing the water content of these batches using appropriate mixture adjustments. (See Box 1)

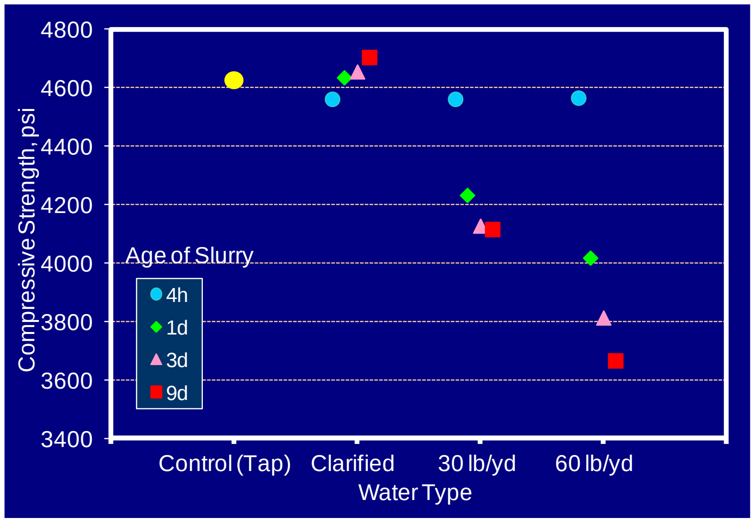


Figure 5 – Compressive Strength at 28 days

The data also show that the batches with the 4-hour old slurry did have a compressive strength similar to the control batches and this is related to the lower mixing water demand and possibly some cementing value from unhydrated cement solids.

Durability Properties

Recycled Water in Ready Mixed Concrete Operations

Data on drying shrinkage, freeze-thaw resistance and rapid chloride permeability were collected and are not included or illustrated in this report. Mixtures that had a higher mixing water content had a concomitant increase in results for drying shrinkage and rapid chloride permeability. These higher values can be offset if appropriate steps are taken to reduce the mixing water content of those mixtures.

Freezing and thawing was conducted in accordance with Procedure A of ASTM C 666, which is the most severe exposure of freezing in water and thawing in water. The samples were exposed to in excess of 600 freeze-thaw cycles. Typical evaluations are conducted for 300 cycles. All the samples had adequate air contents and the durability factor for all conditions exceeded 90% when the tests were terminated. Typical failure criteria for freeze-thaw evaluations are when the durability factor falls below 80% in 300 cycles. The severe exposure of Procedure A, caused scaling of the freeze-thaw specimens. Mass loss quantified to an average 2.5% of the original mass of the specimen. There was no distinct experimental condition that showed a higher level of scaling.

Phase II

The observation that recycled water slurries used at 4 hours did not cause significant detrimental effects on mixing water demand and setting time, the second phase of the study was designed to evaluate whether the treatment of wash water with a hydration stabilizing admixture (HSA) could offset some of the negative effects with high solids recycled slurries observed in Phase I of the study. Phase II also included a condition where the mixing water using recycled water slurry was at the ASTM limit for solids content of 15 lb. per cubic yard.

The same concrete mix design and procedures were used for Phase II of the study. The details of the experimental conditions are listed in Table 3. The data was generated from two replications of the experimental series.

Recycled Water in Ready Mixed Concrete Operations

Table 3 – Experimental variables in Phase II of the Study

Water	• Tap water (Control) • Recycled water at 15 lb solids per cubic yard • Recycled water at 45 lb solids per cubic yard
HSA Treatment	• No admixture • Low Dosage (1.5 day protection) • High Dosage (8 day protection)
Age of slurry	• 4 ± 1 hour • 1 day • 7 days

In this phase of the study, the recycled water slurry was obtained in the same manner and placed in 3 separate containers. Two of these containers were dosed with the hydration stabilizing admixture at two hours after the initial contact of water with the cement. The two hours was chosen to simulate when a mixer truck might return to the plant and washed out with water that contained HSA.

The *Low* dosage was established from other tests to maintain the cement solids from hydrating about 1½ day and the *High* dosage was established to keep the cement solids from hydrating for 8 days. The progression of hydration of the cement (effectiveness of the admixture dosage) was quantified from the loss on ignition on the dry solids from the slurries. These results are illustrated in indicated in Figure 6. A low loss on ignition value corresponds to a low degree of hydration of cement. Data in Figure 6 are from the actual slurries used in the concrete batches.

Within ASTM C 94 Limits

Recycled Water in Ready Mixed Concrete Operations

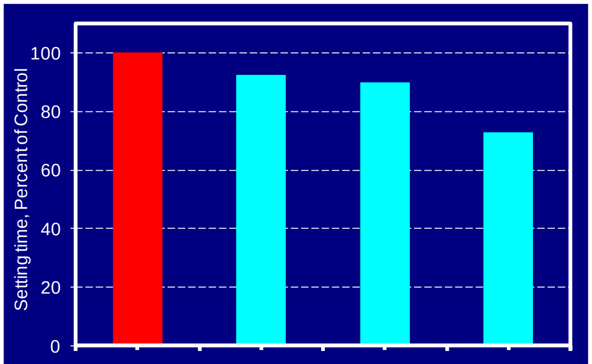
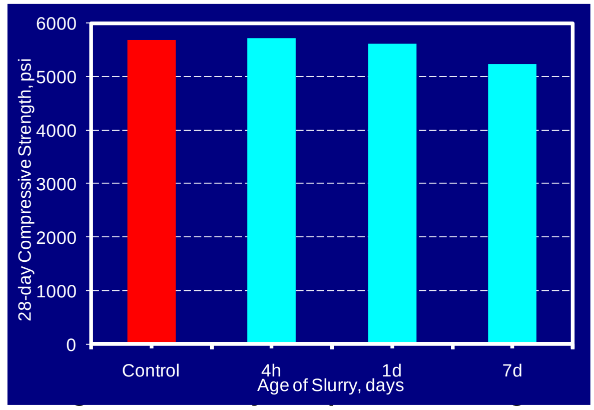


Figure 7 – Setting time of concrete batches with recycled water at the ASTM



for concrete batches with recycled water at the ASTM C 94 solids limit

Figures 7 and 8 illustrate the setting time and 28-day compressive strength of concrete, respectively, of concrete batches with solids content at the 50,000-ppm limit (or 15 lb/yd^3) of ASTM C 94. The slurry ages were 4 hrs, 1 day and 7 days. Mixing water requirements were 0 (at 4 hours) to 15 lbs/yd^3 higher than that of the control batches for target slump.

The data indicate that setting time (expressed as percent of control) and strength were similar to control, except for modest setting time acceleration and lower strength for the batches with the 7-day-old slurry. These deviations from control for concrete with the 4-hour and 1 day old slurries are within permissible limits for water in ASTM C 94.

APPENDIX 3 Ready Mix Concrete

STUDY "RETENTION OF READY MIX PROCESS WATER"

KANE GeoTech, Inc.
Geoengineering Consultants

Retention of Ready Mix Process Water

March 1, 2007

Job No. GT05-27

Prepared for:

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RETENTION OF READY MIX PROCESS WATER

EXECUTIVE SUMMARY

The California Regional Water Quality Control Board, Central Valley Region (RWQCB) has proposed to issue General Waste Discharge Requirements ("Proposed Order") for regulation of the transient onsite storage and disposition of process water generated during ready mix plant operations, particularly the water ("wash water") generated during the rinsing of ready mix trucks. As previously proposed, the Proposed Order will also address related stormwater discharges associated with areas of the plant where rock-out materials and returned concrete are handled. The purpose of the Proposed Order is to prevent the migration of ready-mix process water to groundwater beneath producer facilities.

The California Construction and Industrial Materials Association(CalCIMA), in cooperation with the RWQCB and ready mix producers throughout the State, began a research program with the goal of achieving groundwater protection while being fiscally viable for the State's construction materials industry. In order to optimize the design of these sumps which are used for temporarily holding wash water, a research program was implemented to investigate sump construction materials and practices. Because the Order called for the use of impermeable liners, or equivalent barriers, beneath concrete sumps and pavement, research was directed at optimizing the construction of sumps to meet the requirements.

To evaluate the permeability of concrete, cured concrete samples batched both with and without admixtures were tested for both strength and permeability. Strength testing was done to determine if the admixtures affected concrete strength. Permeability tests also were performed so that the permeability of the concrete in new construction could be reasonably predicted. In a second series of tests, concrete slabs were cast, cracked, and then evaluated for permeability following application of various sealing materials.

Tests showed that plain, uncracked concrete is highly impermeable. In fact, existing uncracked concrete can be as impervious as a geofabric liner. The permeability of plain, uncracked concrete was on the order of 1×10^{-10} cm/s, which is less than most landfill liners. However, waterproofing admixtures were shown to have a negligible effect on reducing permeability and may negatively affect concrete strength.

Tests on cracked concrete slabs indicated that permeability was significantly decreased by the application of concrete paste to the cracks. Since concrete paste is normally present in substantial quantities in ready mix process water sumps, the sumps are likely to be self-sealing in the event that cracking occurs.

RETENTION OF READY MIX PROCESS WATER

TABLE OF CONTENTS

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1. INTRODUCTION

The California Regional Water Quality Control Board, Central Valley Region (RWQCB) has proposed to issue General Waste Discharge Requirements ("Proposed Order") for regulation of the transient onsite storage and disposition of process water generated during ready mix plant operations, particularly the water ("wash water") generated during the rinsing of ready mix trucks, Figures 1 and 2. As previously proposed, the Proposed Order will also address related stormwater discharges associated with areas of the plant where rock-out materials and returned concrete are handled (RWQCB, 2005). The purpose of the Proposed Order is to prevent the migration of ready-mix process water to groundwater beneath producer facilities.

The RWQCB agreed to work with a technical advisory group comprised of the California Construction Industrial Materials Associations (CalCIMA) and representatives of ready mix producers throughout the State's Central Valley (and beyond) to evaluate sump-design materials and design parameters.

CalCIMA requested that KANE GeoTech, Inc. implement a research program to characterize the permeability of concrete in varying configurations and under varying conditions. This Report presents the results of that research.

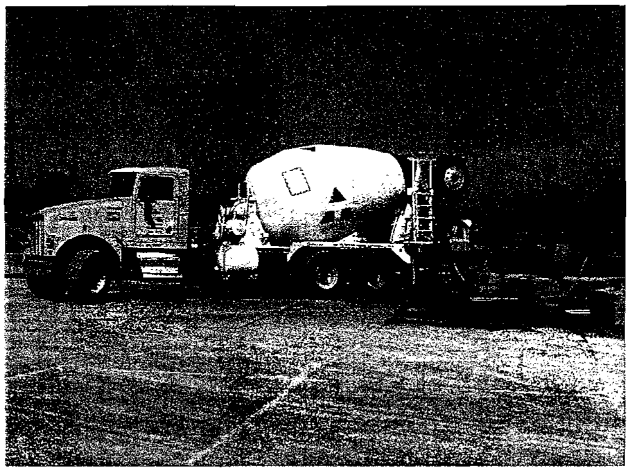

Figure 1. Ready Mix truck washout.

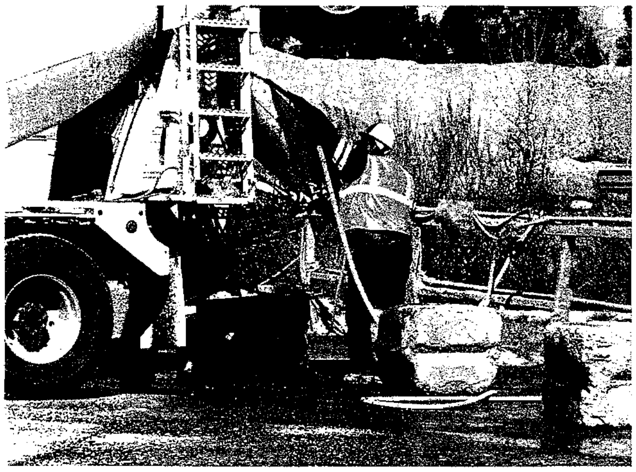

Figure 2. Ready Mix Washout into pond.

2. BACKGROUND

In order to protect groundwater, the RWQCB has proposed that:

- An impermeable liner, or equivalent, be installed beneath and surrounding the concrete process water sump. The impermeable liner could be a geomembrane or geofabric, or an equivalently effective material.

- Existing sump systems be made impermeable through the application of an impermeable surface application.

At the time of the Proposed Order, the RWQCB had no information on the permeability of existing or new concrete, or on the possibility that cracked concrete could be made impermeable. In order to provide the RWQCB with some additional insight on concrete permeability, three areas of investigation were proposed:

1. *Evaluate the inherent permeability of concrete, with and without admixtures.* Many products exist to waterproof concrete and much research has been conducted in the effectiveness of such products. In the United States and other countries, research has been driven by the need to achieve durable and impermeable highway surfaces during winter months when salt (chloride) is applied to melt snow and ice (Scaglione, 2002). These products use a variety of strategies to waterproof concrete including densification, crystal growth in pores and cracks, and hydrophobic pore-blocking additives.

2. *Investigate measures to ensure that cracking of the in-place, cured concrete does not increase permeability.* This would include an assessment of surficial coatings. Macro-cracking of new sumps would be controlled by an adequate application of design standards, that is, the inclusion of reinforcing steel in new construction. However, concrete often exhibits micro-cracking with time. The extent to which these micro-cracks can be sealed ultimately affects the permeability of the concrete structure. Surficial coatings are likely to increase the impermeability of concrete. These coatings vary by method of application, such as brush-on, roll-on, or spray-on, and by content, latexes, resins, and urethanes. Fine-grained materials normally found in ready mix process water sumps may also be effective at decreasing the permeability of otherwise compromised concrete. Ultimately, any surficial coating must also be able to withstand the rigors of plant operations, such as cleaning of the sump using heavy equipment.

3. *Evaluate design methods regarding the structural integrity of concrete sumps and provide recommendations for design specifications.* This area of investigation is not included in this report as CalCIMA has determined that it will retain a registered Structural Engineer to provide this part of the deliverables.

3. SCOPE OF WORK

The Scope of Work for this research included the following:

1. *Concrete Permeability and Strength Testing.* Concrete cylinders were poured and cored to test for both permeability and strength. Additives and coatings were applied to determine their effects on concrete strength and permeability.

2. *Testing of Pilot Scale Cracked Concrete Specimens.* Reinforced concrete slabs were constructed, cracked, and tested for permeability. This was carried out to determine the permeability of existing cracked slabs and suggest possible treatments to reduce their permeability.

This report presents the following:

1. The results of a study of the permeability of concrete, with and without admixtures.

2. The results of a study of concrete cracking and surficial coatings.

4. LITERATURE REVIEW

Much of the research on concrete permeability is related to the migration of chlorides deposited on pavement surfaces during snow operations. In particular, these chlorides cause oxidation of reinforcing bars, expansion of the oxidation product, and subsequent spalling of the overlying concrete. Other areas where concrete permeability is important include subsurface or basement walls and septic tanks.

4.1 Porosity and Permeability

Misconceptions about concrete permeability often arise from misuse of the terms "permeability" and "porosity." Although concrete is porous, it is far from permeable. Porosity is the relative proportion of pores (void space) to the total volume of concrete. Permeability is the ability for fluids to flow through the concrete under a pressure differential, or head. Permeability depends on the connectivity of the pores. Thus, it is very possible for a material to be very porous but virtually impermeable. This is the case with concrete. An everyday analogy might be an inexpensive polystyrene foam (Styrofoam™) drink cooler that owes its lightness to the porosity of the foam but is impermeable to the migration of water through the foam.

Good quality concrete has been shown to be relatively impermeable. In fact, the permeability of concrete decreases with time. This is because the cement inside the concrete continues to hydrate over time, reducing pore connectivity even further. For example, septic tanks that are continuously in contact with moisture actually have their strength and durability increased, and their permeability reduced, over time (Cutler and Frank, 2005).

4.2 Darcy's Law

Darcy's law was developed in 1856 by the French hydraulic engineer Henry Darcy to describe flow through porous media including soil, rock, or concrete, Figure 3. In equation form Darcy's law states:

$$Q = k\frac{\Delta h}{L}A$$

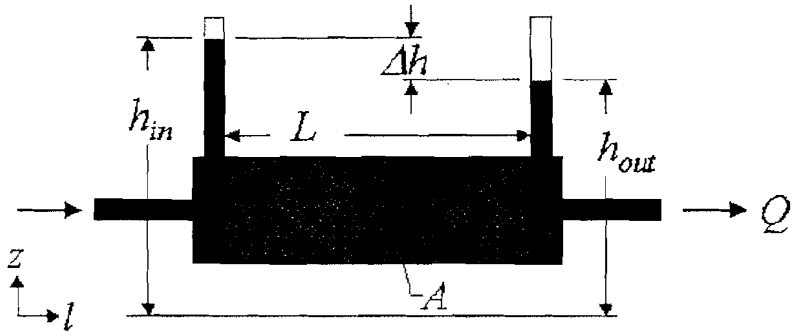

Figure 3. Graphical representation of Darcy's experiment (Brown, 2004).

where,

Q = volumetric flow rate (ft^3/s)
k = hydraulic conductivity (ft/s although usually given in cm/s) (coefficient of permeability)
h = hydraulic (elevation) head (ft)
L = flow path length (ft)
A = flow area perpendicular to L (ft^2)
Δ = change in h over the path L

Darcy's law can be used to calculate the volume of fluid that would flow through a material. Assuming a typical wash out sump of 12-in thick material under a constant 5-ft of elevation head, Table 1 shows the volumes of leachate that would pass through one square foot per year for materials with various permeabilities.

*TABLE 1. YEARLY FLOW THROUGH MEDIA WITH VARYING PERMEABILITY**

k (cm/s)	Volume ($gal/ft^2/yr$)
1×10^{-5}	386.9843935
1×10^{-6}	38.6984393
1×10^{-7}	3.8698439
1×10^{-8}	0.3869844
1×10^{-9}	0.0386984
1×10^{-10}	0.0038698
1×10^{-11}	0.0003870
1×10^{-12}	0.0000387

*Medium is assumed to be 12-in thick with a constant head of 5-ft for the entire year.

4.3 Concrete Permeability Test Methods

In common practice, concrete permeability is often measured indirectly using the method outlined in *ASTM C 1202 – Standard Tests Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration*. However, the test does not directly measure chloride resistance or permeability. The test measures the electrical conductance of the concrete, and thus is an indirect and not a true measure of permeability. In the test procedure, the total amount of electrical current, in coulombs, that passes through a 2-in x 4-in saturated concrete specimen over 6 hours under a constant voltage is determined. However, permeability values have essentially a linear relationship to the charge passed. According to the Transportation Research Board (TRB, 2005), this test can result in misleading values of permeability, especially when fly ash and other pozzolans are contained in the mix.

Another indirect indicator of permeability that is sometimes referred to is the British Absorption test *(BS 1881:Testing Concrete - Part 208)*. The British Absorption Test is not a direct measurement of permeability and was developed for determining the durability of concrete. In this test, an oven dried, concrete cylinder is weighed and soaked in water until fully saturated. It is weighed again and the ratio of absorbed water to the dry weight of the concrete is determined. The assumption is that a continuous capillary pore structure will allow more water to be taken up by the cylinder. Since continuity of the pores is what determines permeability, higher percentages of absorbed water are an indirect measure of the permeability.

A direct and the most accurate method of permeability measurement is *ASTM D5084/Corps of Engineers CRD-C 163-92 Test Method for Water Permeability of Concrete Using Triaxial Cell.* It is a primary rather than secondary method. The test involves establishing steady-state flow through a 6" x 6" high cylindrical concrete specimen. A pressure gradient is induced in a triaxial cell with ambient pressure on one end and a drive pressure, given as a function of the concrete compressive strength, on the other end. Once steady-state flow is established, concrete permeability is calculated. This is the test procedure relied on for this research. The procedure is given in Appendix A.

4.4 Previous Research

Much of the early work on concrete permeability was conducted by Powers, et al. (1954) and Powers, et al. (1959). Powers, et al. (1954) determined that concrete with a water-cement (w/c) ratio below 0.40 had negligible permeability. In Powers, et al. (1959), a chart was published with the elapsed time required to obtain a discontinuous (impermeable) capillary pore structure in the concrete showing how permeability decreases with time.

Scaglione (2002) examined the permeability of cast-in-place prestressed/precast concrete supplied to the Ohio Department of Transportation using ASTM C 1202, discussed above. The test measures the electrical conductance of the concrete rather than the actual permeability and is not a true measure of permeability. The test measures the total amount of electrical current, in coulombs, that passes through a 2-in x 4-in saturated concrete specimen over 6 hours under a constant voltage.

Scaglione (2002) noted that concrete permeability is affected by the water-cement ratio (decreasing w/c results in decreasing permeability) and the type of cementitious (pozzolanic) materials used. The author also noted that slag and microsilica reduces permeability more than fly ash. Russell (2001), however, pointed out that time is an important factor as well.

Nokken (2005) tested the applicability of Powers, et al. (1954; 1959) work using today's concrete product components. She tested concrete cylinders cured for 28-days in a high-pressure (3550-psi) triaxial cell. Water cement ratios varied between 0.30 to 0.90. Results showed that all samples, with the exception of those with w/c ratios of 0.69 and 0.90 achieved capillary discontinuity, i.e., became essentially impermeable at 28-days with permeabilities less than 10^{-10} cm/s.

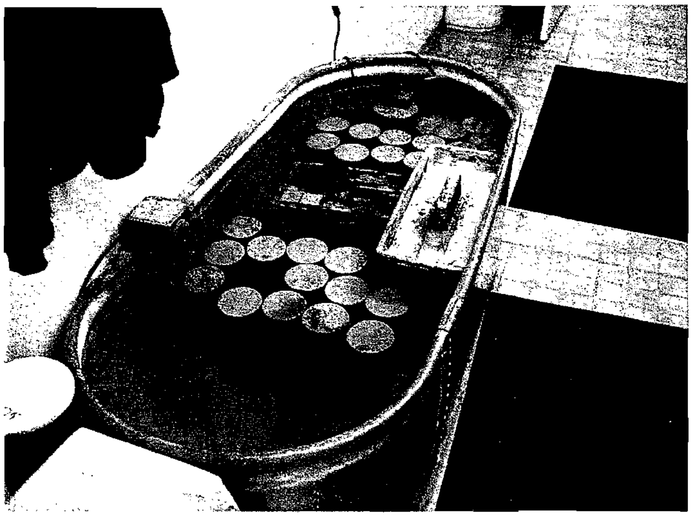

Figure 3. Curing concrete samples in water bath.

5. SAMPLE PREPARATION

The concrete mix designs are given in Appendix B. Test cylinders were prepared by Central Concrete Supply at its Rio Linda, California laboratory facility following the procedures of *ASTM C 31-00 – Standard Practice for Making and Curing Test Specimens in the Field*, Appendix C. Eighteen cylinders were cast and cured for 28 days prior to testing, Figure 3.

In addition, cores were taken in existing concrete surfaces, Figure 4. The concrete was returned ready mix concrete and most likely not poured or installed according to standard practices.

6. CONCRETE CYLINDER PERMEABILITY TESTING

6.1 Introduction

Concrete cylinder permeability was measured using *ASTM D5084/Corps of Engineers CRD-C 163-92 Test Method for Water Permeability of Concrete Using Triaxial Cell*, Figure 5. Tests were performed by Sierra Testing Laboratories, El Dorado Hills, California.

A total of 22 specimens were tested to determine the permeability of conventional Ready Mix concrete and the efficacy of adding admixtures to improve the impermeability. Two series of tests were performed.

The first series of tests evaluated and compared the permeability of a controlled mix of ready mix concrete, with and without admixtures. Six groups of three standard 6-in diameter by 12-in high concrete test molds were poured using mix designs that varied primarily by admixture content. Prior to permeability testing, the 28-day cured cylinders were saw cut on both ends to produce a finished test cylinder of 6-in diameter by just under 12-in high, which complies with the test standard.

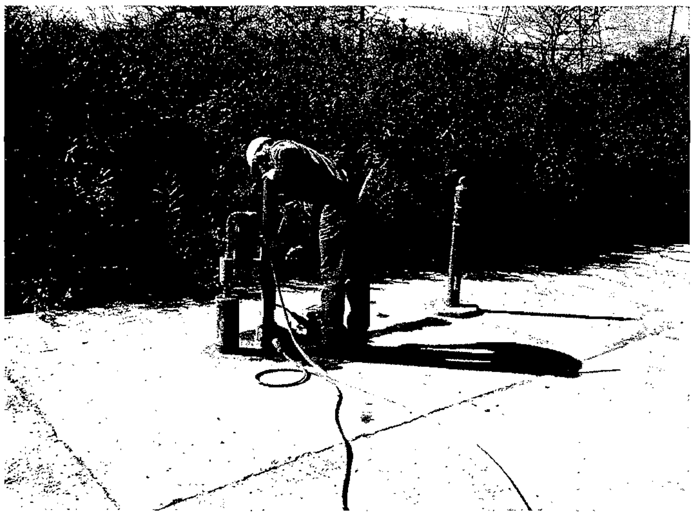

Figure 4. Coring concrete cylinders.

The cylinders were batched on January 4, 2006 and were submitted to Sierra Testing Laboratories for testing beginning in February 2006.

The second series of tests investigated the effectiveness of surficial coatings on existing concrete. Using a commercially available concrete boring machine, 6-inch diameter cores were cut from existing concrete slabs and were trimmed to a 6-inch height (Figure 5). The concrete slab from which the cores were cut was of unknown origin, and most likely not placed using current standard practices. The concrete was excess concrete returned to the ready mix plant, probably because it exceeded accepted age. Surficial coatings were applied to the top cylinder surfaces and the permeability was tested.

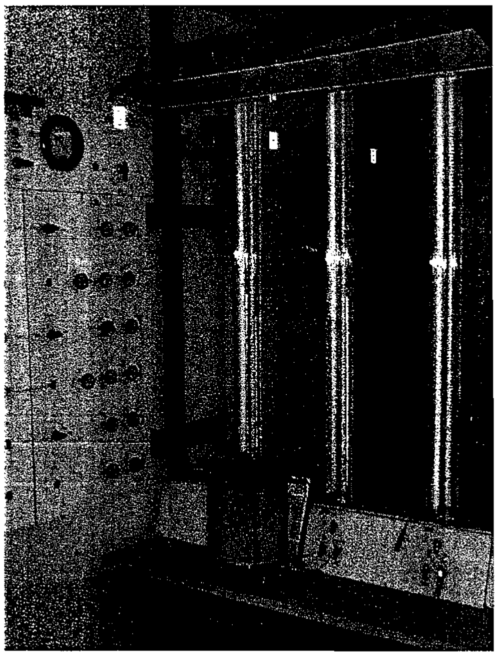

Figure 5. Concrete cylinder in permeability cell.

The second series evaluated the effectiveness of coatings of the permeability of existing concrete. The purpose of these series was to provide insight on the permeability reduction of coatings to existing concrete structures. The age of the concrete before pouring was beyond acceptable in terms of conventional practice. Coatings were applied to the top surface as specified by the manufacturer and the tests performed. In addition, an uncoated control cylinder was tested for permeability.

6.2 Admixtures and Coatings Tested

Admixture #1

Admixure #1reportedly reduces capillary absorption, wick action, and permeability under pressure. According to the manufacturer, Admixure #1 works by blocking concrete pores with undisclosed "hydrophobic" ingredients. The manufacturer's literature contrasts its performance with pozzolans, which reduce permeability by densifying the concrete, and "crystal growth" type additives which reduce porosity by filling pores with crystals. In addition, it was claimed to reduce water intake (absorption) by 92% compared to 13% for crystal-growth admixtures, and reduce chloride penetration 100% compared to 25% for crystal-growth additives. It should be noted that actual test values were not provided and that these tests are indirect measures of concrete permeability.

Admixure #2

Rather than crystal growth, Admixure #2 utilizes hydrophobic chemicals to waterproof concrete. The company supplies data on the British Absorption Test with absorptions of 0.4% to 0.9% compared to its control mix of 2%.

Admixure #3

Manufacture's literature for Admixure #3 supplies test data from Materials Testing Corporation concerning two tests on concrete cores using *ASTM D 5084*. The cores had permeabilities of 4.4×10^{-9} cm/s and 5.7×10^{-9} cm/s.

Admixure #4

Admixure #4 literature states that it reacts with cement hydration by-products to form pore-clogging crystal fibers. The net reduction in pores and continuity results in decreased permeability. As a coating, Admixure #4 ostensibly migrates through the concrete by osmosis and then forms crystals within the pores. The manufacturers of Admixure #4 do not supply any data in its literature comparing its effectiveness when compared with other products.

Admixure #5

Admixure #5 also forms non-soluble dendritic crystals which serve to clog concrete pores and seal the concrete. The manufacturer of Admixure #5 did not supply any data to compare with other products.

6.3 Results and Discussion

6.3.1 Admixture Results

The results of the permeability analyses are presented in Appendix D. For the batched-concrete test cylinders, the results of each group of three cylinders were averaged. All concrete cylinders had permeabilities averaging less than 10^{-9} as shown in Table 2. These values are very low. For example, fresh concrete would allow only about 0.19-gal/yr of leachate to seep through a 10-ft wide x 50-ft long x 1-ft thick sump under a constant head of 5-ft of process water. As shown in Table 2, admixtures do little, if anything, to improve the permeability characteristics of concrete.

TABLE 2. AVERAGE PERMEABILITIES FOR CONCRETE CYLINDER TESTS

Sample	Average Permeability (cm/s)
Plain Concrete	6.02×10^{-10}
Admixture #1	4.20×10^{-10}
Admixture #2	3.97×10^{-9}
Admixture #3	1.59×10^{-9}
Admixture #4	2.45×10^{-10}
Admixture #5	5.67×10^{-10}

6.3.2 Coating Results on Cored Samples

Because of the extremely low permeability of the poured plain concrete cylinders, coatings were not applied to poured, first series, cylinders. However, a readily-available conventional coating was applied to the cored cylinders. The average permeability of the coated, cored cylinders was 6.35×10^{-9} cm/sec.

7. CONCRETE STRENGTH TESTING

7.1 Background

Compressive strength(f'_c) is the most important concrete property with regard to structural design. Although high strength concretes with strengths greater than 10,000-psi can be designed, strengths of 3,000-psi to 6,000-psi are normally used in construction. For ordinary construction, designs are generally based on a minimum of 3,000-psi concrete specified although 4,000-psi is frequently specified as well.

Testing was performed as per *ASTM C31 Standard Practice for Making and Curing Concrete Test Specimens in the Field* and *ASTM C39 Standard Test Method for*

Compressive Strength of Cylindrical Concrete Specimens (ASTM, 1999). Standard acceptance criteria defines the strength as the average of two cylinders, measured at 28 days and molded from the same concrete batch (ACI, 2000).

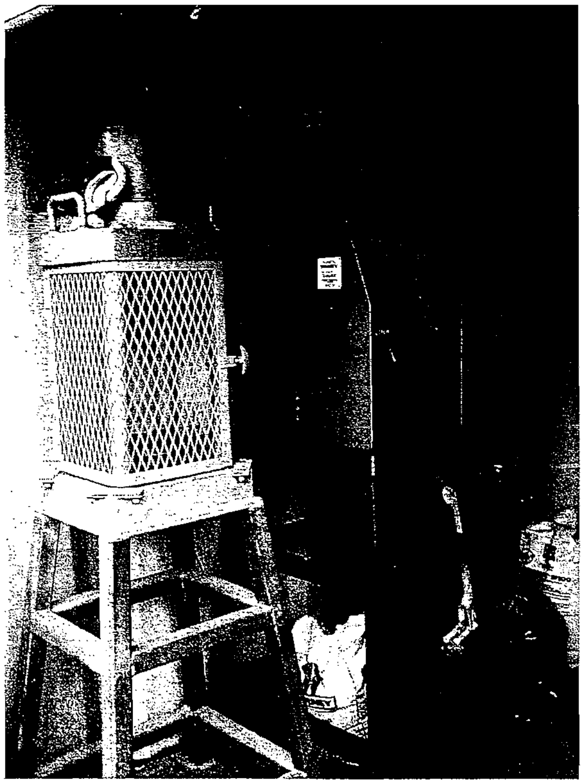

Figure 6. Compression testing apparatus.

7.2 Justification

In the structural design of concrete, increased strength can result in smaller member sizes and a reduction in the area of steel required for given loads. This would be especially true when new sumps are designed. In addition to reducing the cost of the structures, any increase in strength would also result in reduced cracking. If the integrity of the structure remains high then overall permeability would remain low. Permeability reduction admixture suppliers often claim that their products would also enhance the strength of concrete as a secondary benefit. The five admixtures tested were also analyzed for their effectiveness in increasing the 28-day strength of the mix.

7.3 Methodology

Concrete cylinders for compression testing were poured from the same batches as used for the permeability samples, that is, the first series. Samples were made at the Central Concrete Supply facility in Rio Linda, California. Two 4-in x 8-in cylinders were made for each of the five admixture types and the control. Cylinders were kept in a constant temperature and humidity facility until testing. Testing was carried out using a compression testing machine, Figure 6. Two cylinders were tested and the average was calculated and reported. Mix designs are given in Appendix B.

7.4 Results

All samples were well above the commonly used 28-day compressive strength design value of 4,000-psi, Table 3 and Figure 7. The average strength of all the mixtures was 5,228-psi with a standard deviation of 567-psi. With one exception, all admixtures resulted in 28-day compressive strengths lower than the control. The control strength was 5,550-psi while only one at 6,020-psi was significantly stronger than average. One admixture, at 4,380-psi, was the only sample to show a significant reduction in strength.

8. CRACKED CONCRETE SLAB PERMEABILITY TESTING

8.1 Introduction

In order to simulate an actual field installation, KANE GeoTech, Inc. worked with Sierra Testing Laboratories, Inc., El Dorado Hills, California to construct "pilot-scale" samples of

TABLE 3. AVERAGE 28-DAY COMPRESSIVE STRENGTHS FOR CONCRETE CYLINDERS

Sample	Avg. Compressive Strength (f'_c) (psi)
Plain Concrete	5,550
Admixture #1	4,840
Admixture #2	4,380
Admixture #3	5,310
Admixture #4	6,020

cracked concrete slabs for permeability. A pilot-scale test stand was constructed and testing performed at Sierra Testing's laboratory, Figure 8. Additional photos are provided in Appendix E.

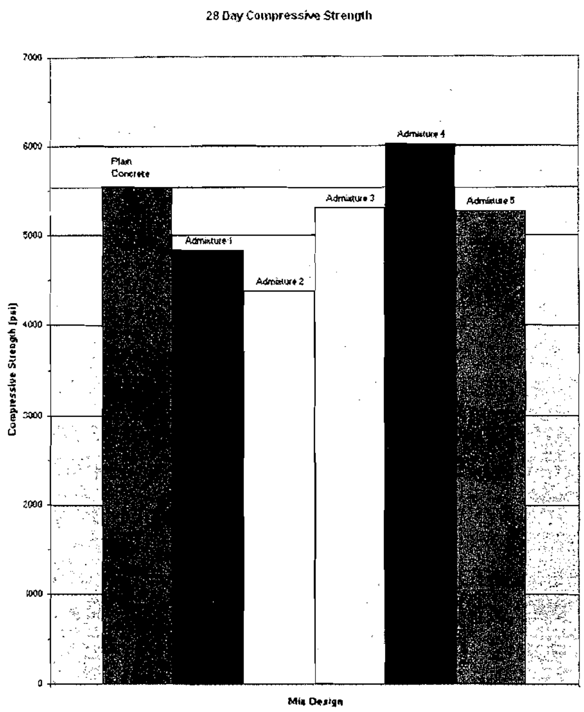

Figure 7. Relative concrete strengths from compressive strength tests.

Four test panels were cast for this phase of testing. Due to time constraints they were allowed to cure for seven days and cracked. Hydraulic conductivity tests were then performed to determine the rate at which water could pass through a cracked concrete slab. Once the flow rate was determined, the panels were coated with concrete sealant products and tested again in order to observe any difference between flow rates. An attempt to quantify crack length and aperture as function of area was unsuccessful. Slabs were deliberately cracked to a much greater degree than anticipated in the field: about 1.5 linear feet of cracking per 1-ft^2 of slab, and aperture, up to 1/4". This was done to insure the timeliness of obtaining data.


Figure 8. Cracked concrete slab test stand.

Coatings used were two of the readily available commercial products available for surficial sealing applications. Because work by Walker (2006) indicated that cement paste can have a permeability as low as 1 x 10^{-9}, concrete paste was included in the crack testing program.

8.2 Materials and Methods

A commercially available concrete sack mix was mixed to the proportions designated by the manufacturer, utilizing a standard drum mixer. A 2-ft x 2-ft form was constructed using 2-in x 6-in pine timbers. This resulted in a final panel thickness of 5.5-in. Steel mesh reinforcing, with a mesh size of 4-in x 4-in was used to reinforce the panels yet allow cracks to develop readily. The panels were cast, and allowed to cure for a period of seven days. On the seventh day of curing the panel was cracked. Sides were placed on the slab and a head of sump water applied. The panels were saturated by immersing in water tanks for a period of 72 hours prior to permeability testing. Initial hydraulic conductivity tests were performed as described in *ASTM D2434-68 Standard Test Method for Permeability of Granular Soils (Constant Head)*.

Upon consecutive stable readings, the samples were air-dried and coatings applied per manufacturer's instructions. About ½" thick layer of cement paste was applied using a spatula. The coated samples were allowed to cure for a period of 48 hours while the cement paste was allowed to cure for 72 hours. Once the curing period was achieved the samples were then submerged for a period of 72 hours to achieve saturation. After the saturation period, hydraulic conductivity tests were run on the coated panels. As stated earlier, although it was originally planned to relate cracking intensity to permeability, results were indeterminate.

8.3 Results

As stated earlier, slabs were deliberately cracked to a much greater degree than anticipated in the field: about 1.5 linear feet of cracking per 1-ft^2 of slab, and aperture, up to 0.38-in (3/8-in). This was done to insure the timeliness of obtaining data. Therefore, initial and final permeability of the cracked slabs would be expected to be much lower, perhaps increased by an order of magnitude, but probably, more.

The results of the hydraulic conductivity tests on the cracked slabs showed a significant decrease in the rate of flow through the test panels when the cement paste was applied. With a rate of approximately 3-cm/sec without a coating, and a reduced rate of 1.2 cm/sec using a commercial concrete sealer, it was determined that a low viscosity coating would not be sufficient to retard the hydraulic conductivity of the wash-out facilities. However, the rate of hydraulic conductivity slowed to a rate of 2.5×10^{-5} cm/sec when the cement paste was used. Laboratory data is contained in Appendix E.

Sierra Testing Laboratories, Inc., El Dorado Hills, California performed hydraulic conductivity tests on multiple concrete samples to determine a cost effective method to slow permeability on cracked concrete slabs. They determined that cement paste, mixed to a water/cement ratio of 0.50, significantly slowed hydraulic conductivity.

9. SUMMARY AND CONCLUSIONS

9.1 Summary of Results

The test results indicate the following:

1. *Plain, uncracked concrete is highly impermeable.* The permeability of plain, uncracked concrete is on the order of 1×10^{-10} cm/sec, which is less than most

landfill liners. For example, the Middlesex County, New Jersey municipal landfill utilizes a liner of 1 x 10^{-7} cm/sec (1-in of seepage water every 30 years (Middlesex County, 2006).

In addition, the literature indicates that low water/cement ratios (≤ 0.40) enhance the impermeability of the concrete. Permeability is likely to further decrease with time, as continued crystal formation strengthens the concrete and decreases the porosity. Finally, the permeability of a concrete structure will decrease with increased concrete thickness, as is illustrated by Darcy's law.

2. *Admixtures and coatings recommended for permeability reduction may not, in fact, reduce permeability.* Over the short time frame of this study, the addition of permeability-reducing admixtures had mixed results. Analysis of older samples of concrete treated with permeability-reducing admixtures may indicate decreased permeability, but such analyses were not within the scope of this study.

3. *Concrete strength is not significantly improved by the use of permeability enhancing admixtures.* The control mix was much stronger than the strength value conventionally used for design.

4. *Older, uncracked, existing concrete can be as impermeable as a geofabric liner.* Concrete permeability decreases with age. The cored specimens of returned concrete had permeabilities as low as 8.96 x 10^{-9} cm/sec. This was nearly the same as the permeability of some of the concrete batched from scratch under highly controlled conditions. Older concrete structures can be expected to be extremely impermeable as long as the integrity of the structure is maintained.

5. *Concrete paste is an excellent permeability reducer.* Under the conditions of the pilot-scale test, the concrete paste alone proved capable of reducing permeability of cracked concrete by 5 orders of magnitude (i.e., 100,000 percent).

9.2 Conclusions

Based on the results of this research, the following conclusions can be made:

1. *A concrete sump with structural integrity has more than adequate impermeability to protect groundwater.* A secondary containment, such as a geofabric liner, will not improve the performance of the sump system.

2. *Cement paste is an excellent sealant for cracks in concrete sumps.* The pilot-scale evaluation of permeability of a grossly cracked concrete slab indicated that even cracked slabs with wide crack apertures can be rendered virtually impermeable with concrete paste. Test slabs were not constrained at the ends and had wider apertures than would be found in an actual pond. Fresh paste was used in the testing. It is reasonable to expect that the paste will become even more impermeable with time. In addition, the existence of a constant head over time in an actual pond will force paste quickly into cracks where it can bond with the concrete. Therefore, test slabs are likely to be much more permeable than an

actual field installation. Therefore, concrete paste is probably the most effective means of reducing the permeability of cracked slabs.

The fact that concrete paste is a component of ready mix truck wash-out means that the ponds are essentially self sealing. The hydrostatic head of the wash-out pond should be sufficient to force the paste into existing cracks. Therefore, existing concrete ponds should not require any retrofit unless structural or capacity improvements are desired.

This research has demonstrated that the concerns associated with potential impacts to groundwater from concrete-lined wash-out sumps assumed by the Proposed Order are most likely unfounded. The pilot-scale slab testing could be investigated further, although it is anticipated that permeabilities will be shown to be much less than those determined in this research.

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11. LIMITATIONS

The analyses, conclusions and recommendations contained in this report are based on our observations and interpretations of the information obtained or provided to us. Our professional services were performed, our findings obtained, and our recommendations proposed in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties either expressed or implied. Findings and statements of professional opinion do not constitute a guarantee or warranty, expressed or implied.

***KANE* GeoTech, Inc.**

William F. Kane, PhD, PG, PE
President, KANE GeoTech, Inc.

REGISTERED PROFESSIONAL ENGINEER
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Exp. 12-31-08
CIVIL
STATE OF CALIFORNIA

APPENDIX 4 Ready Mix Concrete Study - RESULTS OF CONCRETE WASHWATER AND SAMPLING AND ANALYSIS

Walker & Associates, Inc.
Geochemistry • Engineering • Remediation • Archaeology

RESULTS OF CONCRETE WASHWATER POND SAMPLING AND ANALYSIS

CMAC MEMBER SITES
CENTRAL VALLEY, CA

June 15, 2006

Submitted to:

Mr. Charles Rea
Construction Materials Association of California
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Walker & Associates, Inc.
Geochemistry, Engineering, and Occupational Health

RESULTS OF CONCRETE WASHWATER POND SAMPLING AND ANALYSIS

CMAC MEMBER SITES
CENTRAL VALLEY, CA

June 15, 2006

SIGNATURE PAGE

Prepared by:

____

William J. Walker, Ph.D. Date
Principal Geochemist

____

Lara Pucik Christensen Date
Senior Environmental Chemist

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 PURPOSE

This document reports and discusses the results of sampling and analysis of water from concrete washwater ponds belonging to members of the Construction Materials Association of California (CMAC). Four sites in the Central Valley (identified as Sites 1, 2, 3 and 4) were sampled. The primary objectives of the sampling program were to:

- Describe in general terms, the facilities including pond size, whether the plants are wet plants or dry plants and a brief description of whether stormwater enters and impacts the pond water.
- Compare the chemistry of washwater among the various sites,
- Determine the metals and other chemical constituents within the washwater ponds to determine the variability among different processing areas, and
- Determine the concentration of hexavalent chromium (Cr(VI)) in washwater and the variability in Cr(VI) among the different sites.

2 SAMPLING AND ANALYSIS

Based on previous investigations, washwater ponds from concrete facilities can contain elevated Cr(VI) and high pH (8 or higher). Pondwater and surface water sampling and analysis conducted to date at some of these facilities does not indicate that any other constituents are clearly elevated with respect to background concentrations or clearly exceed levels protective of water quality. However, to ensure that washwater will not affect underlying soils and groundwater, other metals and chemical constituents were measured as part of this program.

Since the composition of the water in the pond discharge areas and the residual concrete is highly variable, it was necessary to examine the metal content of the washwater using the CAM 17 metal scan which includes: (Antimony (Sb), Arsenic (As), Barium (Ba), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Lead (Pb), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Selenium (Se), Silver (Ag), Thallium (Tl), Vanadium (V) and Zinc (Zn)).

2.1 Sampling Site Descriptions

In general, the ponds at all sites were rectangular in shape, sloped on the bottom, constructed of concrete and bermed on 3 sides. The narrow, unbermed shallow end of the ponds provided access to trucks for washing and for sludge removal. At all sites, water and sludge from the ponds was collected and recycled back through the plants.

Diagrams of site washwater pond facilities are provided in Figures 1 – 4. Individual site descriptions are provided below:

Site 1: Single pond approximately 13' x 30'. Stall depth ranged from about 0 to 7 feet. Standing water ranged from about 6" to 4.5'. Make-up water obtained from city supplies comprised of surface and groundwater sources.

Site 2: Series of 5 parallel stalls each approximately 14’ wide and 25’ long. Stall elevations and drain holes in the stall walls provided drainage from the highest to the lowest stall. Standing water depths ranged from approximately 0’ to 3’. Sump pump in lowest stall transferred water to recycle/holding tank. Trucks exiting the site were externally rinsed at another location. Rinsate from this washing area flowed across the site into the lowest stall.

Site 3: Main settling/holding pond approximately 25’ x 50’ and ranged from about 0’ to 5’ in depth. Depth of standing water in the pond at the time of sampling was approximately 3’ at the deep end. Perpendicular to the main holding pond were three stalls approximately 8’ by 30’ wide. One stall received rinsate from the truckwash, one stall was dry, and one stall contained sludge. Stalls were plumbed so that transfers between stalls and to the main holding pond were individually controllable. Make-up water obtained from city supplies.

Site 4: Series of three parallel stalls each approximately 20’ x 60’. Stall depth ranged from approximately 0’ to 6.5’. Depth of standing water in the deep end at the time of sampling was approximately 2.5’. One stall was primarily used for washing and the following two for settling. Makeup water obtained from private groundwater supply.

Because the ponds at all sites are bermed on three sides and open on one end, the ponds could potentially receive stormwater runoff from the vicinity of the pond. In general, this potential stormwater drainage area qualitatively appears to be no larger than approximately 10 times the size of the pond.

2.2 Sampling Methodology

Three grab samples (see Figure 1-4) were collected from each washwater pond using the following protocol:

- To prevent stormwater dilution, sampling was conducted at least 72 hours after a rainfall event.

- A sketch of the site was drawn showing the location of the samples from each pond.

- A stream sampler (extension pole with sampling cup) was used to collect a surface sample from the pond at each location (See Figures 1 through 4 for sample locations within each pond). Between samples the sampling cup was cleaned using normal Alconox rinsate followed by 3 rinses with distilled water.

- The sample from each pond location was transferred into a 1 L acid-washed laboratory bottle provided by the laboratory. This sample was immediately placed into a cooler with ice. Additional sample was transferred into a beaker for on-site field analysis.

- The sampling procedure followed Method 1669, the "clean hands/dirty hands technique" recommended for trace metals sampling and analysis. This method requires that the sampler don non-powdered gloves while sampling and the transfer of the sample into the container without touching the container. After transferring the sample, the sampler dons a clean pair of gloves and transfers the container into a double lined plastic bag.

- pH was measured in-field using a Hanna portable pH meter that was 3 point calibrated upon arrival at each site (see pH discussion in the next section).

- Hexavalent chromium was measured in the field using a Hach Portable DR2010 Spectrophotometer and appropriate colorimetric reagent kits.

- The samples were delivered to CLS Laboratories in Rancho Cordova, CA on the same day they were collected under standard Chain-of-Custody procedures.

- At CLS Labs, a composite of the 3 samples collected from each pond was made. All analyses conducted by CLS were then conducted on the composite sample.

2.3 Analytical Methods

The samples were analyzed at CLS Labs in Rancho Cordova, CA for the following constituents via the following methods:

- Specific Conductance, TDS, Bicarbonate alkalinity and pH by standard EPA/STDM methods (9040 B for pH). Please see the pH discussion below.

- Cr(VI), total and dissolved, by EPA Method 7199,

- Unfiltered CAM 17 metals (Arsenic, Mercury, Antimony, Barium, Beryllium, Cadmium, Chromium, Cobalt, Copper, Lead, Molybdenum, Nickel, Selenium, Silver, Thallium, Vanadium, and Zinc) by EPA 6010B/6020/7000 series methods, and

- Dissolved Metals including Cr (VI), aluminum, boron, barium, calcium, chromium (total), iron, potassium, magnesium, molybdenum, sodium, and vanadium by EPA 6010B/6020/7000 series after filtration through a 0.45 micron filter.

The standard pH method used by the certified laboratories calls for a 2 point calibration consisting of pH 4 and pH 7 buffers. Occasionally, if the laboratory technician notes that the pH is very high (> 8.5), the calibration will be done using a pH 10 buffer as well. Concrete washwater is known to have a high pH due to the high $Ca(OH)_2$ content, which can cause pH to increase to 11 or higher. This presents problems for accurate pH measurements due to the following facts (see *Instrumental Methods of Analysis*, Willard et. al. 1981, Van Norstrand and Company, New York, Chapter 22):

- As pH increases or decreases from neutral, the proportion oh hydroxyl ions (base) to protons (acid) changes dramatically. Since pH is a log scale, at pH 12 the activity of OH^- is 10^{-2} and H^+ is 10^{-12} . This small activity presents diffusion controlled problems at the glass electrode interface such that true measurement of pH is difficult.

- Because the electrode suffers from problems at very high pH, the only way that accurate pH can be achieved is through the use NIST standards composed of $Ca(OH)_2$ buffered at pH 12.1. This method was used in the field measurements performed by Walker & Associates, Inc, but not by the certified laboratory. In addition, 3 point calibration was typically used to achieve a Nernstian response (59 mv/unit change in pH) over the pH range of 2 to 12.1.

- Therefore, in the sections that follow, the field pH is the more reliable of the two measurements and should be used in data interpretation.

Also, it should be appreciated that there are few laboratories capable of performing low level or trace metal analysis. For example, in the case of low level mercury determination, only a few labs on the West Coast are capable of performing this analysis. As regulatory concentration limits continually become smaller in surface water and groundwater, more advanced instrumentation is required such that fewer and fewer laboratories can actually reliably perform the determinations. Given the short holding times (eg. 24 hrs in some cases) it is likely that high quality data will become more and more difficult to achieve.

3 RESULTS AND DISCUSSION

3.1 Chemical Data

Results of certified laboratory analyses on the site composite samples are summarized in Table 1. Copies of original laboratory reports are included in the Appendix. Results of the in-field analysis are shown in Table 2.

As shown in Table 2, field-measured pH at the four sites ranged from 8.3 to 12.4 for the individual samples; laboratory-measured pH on the site composites ranged from 11.89 to 12.32. Table 1 shows that total hexavalent chromium ranged from 39 to 540 ug/L, most of which was in the dissolved phase. In-field results of the individual locations sampled at each site reveal that hexavalent chromium concentrations can vary greatly within a given washwater system. At site 4, for example, Cr(VI) concentrations ranged from 10 to 80 ug/L (Table 2). Other sites also typically had one location within the washwater system exhibiting a higher Cr(VI) concentration than the rest of the system.

Most of the differences shown in Table 2 between the field-based sample average and certified-laboratory composite analysis results for Cr(VI) fall within relative error of measurement (approximately +/- 25%), which is the allowable relative percent difference (RPD) limit reported by the laboratory for QA/QC matrix spike duplicate samples. Some difference is likely attributable to the comparison of an average obtained from three individual sample measurements made immediately in the field to a single composite sample collected, mixed, and then measured in the laboratory. Error of measurement is also generally greater for onsite versus laboratory testing due to tighter control achievable in the certified laboratory.

At Site 1, an arsenic concentration of 350 ug/L was also observed in conjunction with a lead concentration of 180 ug/L.

3.2 Significance of Chemical Data: Source of Metals and Fate and Transport

As expected, the variability of hexavalent chromium within the site washwater systems indicates that the systems are highly dynamic. This is likely due to a combination of physical and chemical processes occurring within the ponds.

The ponds behave in some ways like a lake that experiences rapid turnover due to addition of washwater and also possibly due to addition of stormwater (see next section). Addition of water from any source causes the ponds to become turbid due to the sediment at the bottom which can cause local increases hexavalent Cr and other constituents. The ponds have areas with fine grained sediments that may or may not easily re-suspend; the overall effect is one of unpredictability in terms of soluble hexavalent Cr in any given part of the pond.

Other factors that control metal concentrations include the source of the concrete in the washwater, the volume and mass of concrete released to the pond, and the source of makeup water used at each plant. For example, at Plant 1, elevated Pb, Zn, Cu and As are also found along with lower amounts of hexavalent Cr. The source of these metals might be linked to the geologic units from which make-up water for the plant is drawn.

One of the key questions concerning washwater ponds is whether Cr(VI) and other metals found in the water will migrate through the paste into the vadose zone (unsaturated zone above groundwater) and then into shallow groundwater. For this to occur, the subsurface must be permeable enough to allow water and dissolved metals to migrate vertically. In addition, the vadose zone contains minerals with surfaces that can adsorb metals and/or change their oxidation state to less soluble forms. If the subsurface is hard to permeate and contains a high adsorption capacity, then groundwater may not be impacted by pond water.

An example of this type of situation is shown in Figure 5, a boring log from a site to which concrete paste and washwater has been disposed for decades. There are several important features about the log that should be noted:

- The concrete paste is easily identified in the log. It occurs as a mainly white to grey colored material, usually very moist to saturated and contains Cr(VI) in concentrations up to 500 ug/kg.

- Below the concrete paste there is an abrupt transition to native soil. Here the soil is only moist (not saturated) and, most importantly, does not contain detectable Cr(VI).

- This boring shows how concrete paste deposits form a very low-permeability layer that does not allow Cr(VI) to migrate vertically into groundwater. In-field saturated hydraulic conductivity ranges from 10^{-10} to 10^{-12} cm/s, which is extremely small.

In addressing the possible role that chemical reactions have on the migration of Cr(VI), a bench test was conducted to determine if the subsurface contained minerals that could reduce Cr(VI) to Cr(III). Cr(III) is very insoluble and will precipitate as an oxyhydroxide upon formation. It is well known that Fe(II) is an effective reducing agent for Cr(VI) and is widely used for groundwater remediation. The bottom layer of soil in the boring log shown in Figure 5 shows that soils just above groundwater contain pyrites, which are an Fe(II) mineral. A sample of this material was placed in a beaker containing washwater with about 200 ug/L of Cr(VI) and allowed to equilibrate for 24 hrs. After that time, the solution was removed by vacuum filtration and Cr(VI) measured again. Figure 6 shows that Cr(VI) in this test was reduced from 200 ug/L to less than 30 ug/L. The subsurface thus demonstrates some capacity to effectively attenuate vertically migrating Cr(VI).

Therefore, if predicting potential groundwater impacts were to be of interest, several contributing factors would need to be considered. These include:

- Evaluating the effectiveness of the paste in “sealing” against migration and the ability of the subsurface minerals to attenuate Cr(VI). The extent of attenuation, leaching, or migration could then be factored against the depth to groundwater, the total metal loading the soils encounter, and their attenuation capacity.

- Some additional sampling to accurately characterize annual variability in the ponds. Because hexavalent chromium was encountered in varying levels within in a single pond and across the sites sampled, it is clear that this event represents only a single "window" of Cr(VI) in washwater.

4 SUMMARY AND CONCLUSIONS

Washwater ponds from concrete facilities can contain elevated Cr(VI) and high pH (8 or higher). Pondwater and surface water sampling and analysis conducted to date at some of these facilities does not indicate that any other constituents are clearly elevated with respect to background concentrations or clearly exceed levels protective of water quality. However, to ensure that washwater will not affect underlying soils and groundwater, other metals and chemical constituents were measured as part of this program.

Results of sampling at the 4 sites indicate that:

- Field-measured pH at the four sites ranged from 8.3 to 12.4 for the individual samples; laboratory-measured pH on the site composites ranged from 11.89 to 12.32.

- Total hexavalent chromium ranged from 39 to 540 ug/L, most of which was in the dissolved phase.

- In-field results of the individual locations sampled at each site reveal that hexavalent chromium concentrations can vary greatly within a given washwater system. At site 4, for example, Cr(VI) concentrations ranged from 10 to 80 ug/L. Other sites also typically had one location within the washwater system exhibiting a higher Cr(VI) concentration than the rest of the system.

- At Site 1, an arsenic concentration of 350 ug/L was also observed in conjunction with a lead concentration of 180 ug/L, it is possible that elevated arsenic is due to the make-up water from the plant.

While Cr (VI) was found in the ponds, it may not represent a threat to groundwater due to the low permeability of the paste in the ponds and the minerals in the subsurface that may reduce and attenuate Cr(VI) before it can reach groundwater (see section 3.2).

5 QA/QC

Field measurement instruments were calibrated and checked according to manufacturers' directions upon arrival at each site, as noted pH was calibrated using a 3 point method with a pH 12.1 NIST buffer to ensure accurate results at high pH.. All instruments were cleaned with Alconox and then triple rinsed with deionized water between sample locations.

Samples for outside laboratory analysis were collected with a grab sampler on a rod directly into unused disposable containers and transported on ice under chain-of-custody documentation directly to CLS Labs in Rancho Cordova, CA within approved method holding times.

CLS is a California certified lab. Their analytical reports include QA/QC data consisting of:

- Method Blanks
- Dirty hads/clean hands
- Laboratory Control Spikes
- Matrix Spikes
- Summary of duplicate results and recoveries and appropriate flags for qualified data.

FIGURES

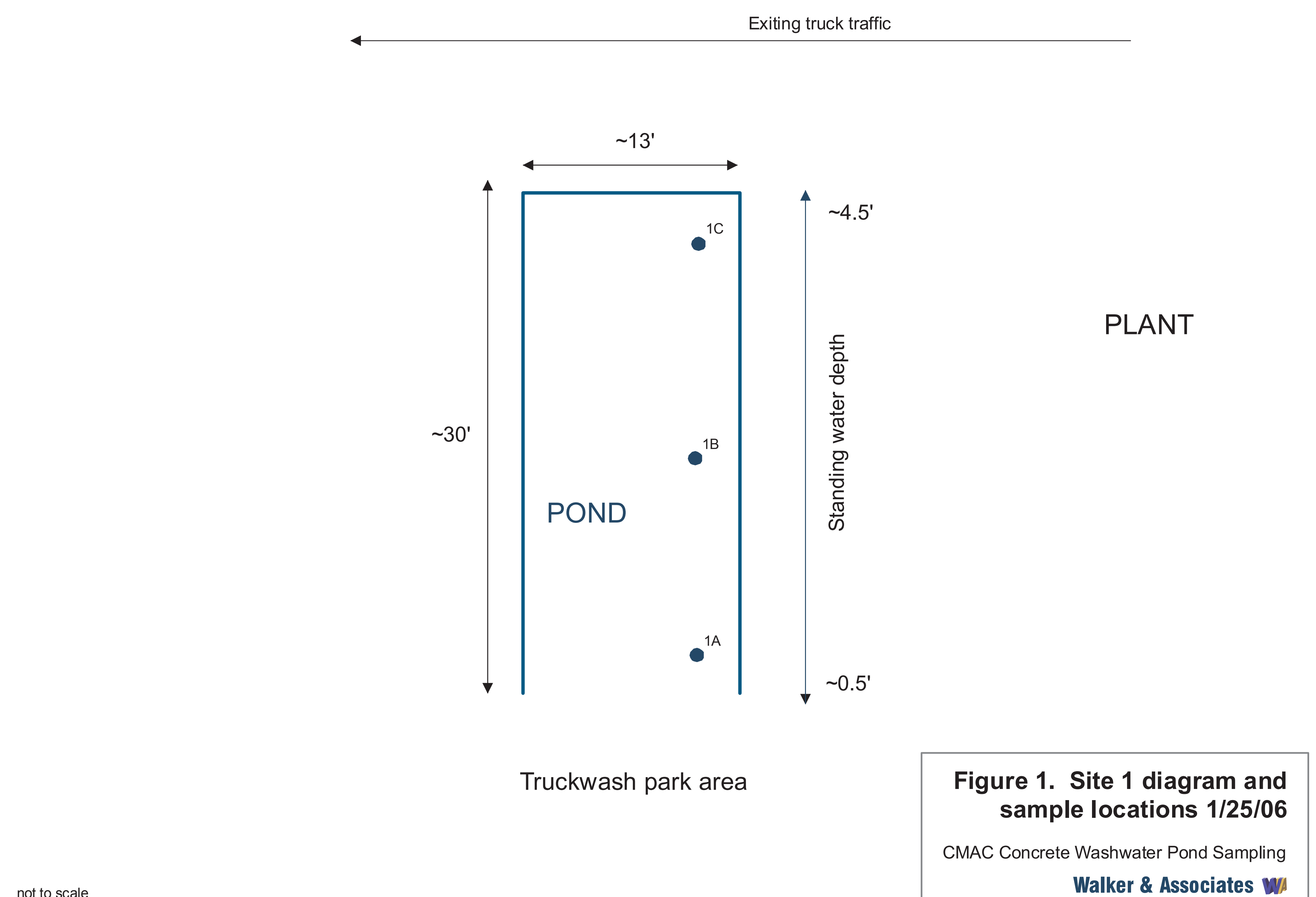


Figure 1. Site 1 diagram and sample locations 1/25/06

CMAC Concrete Washwater Pond Sampling

Walker & Associates

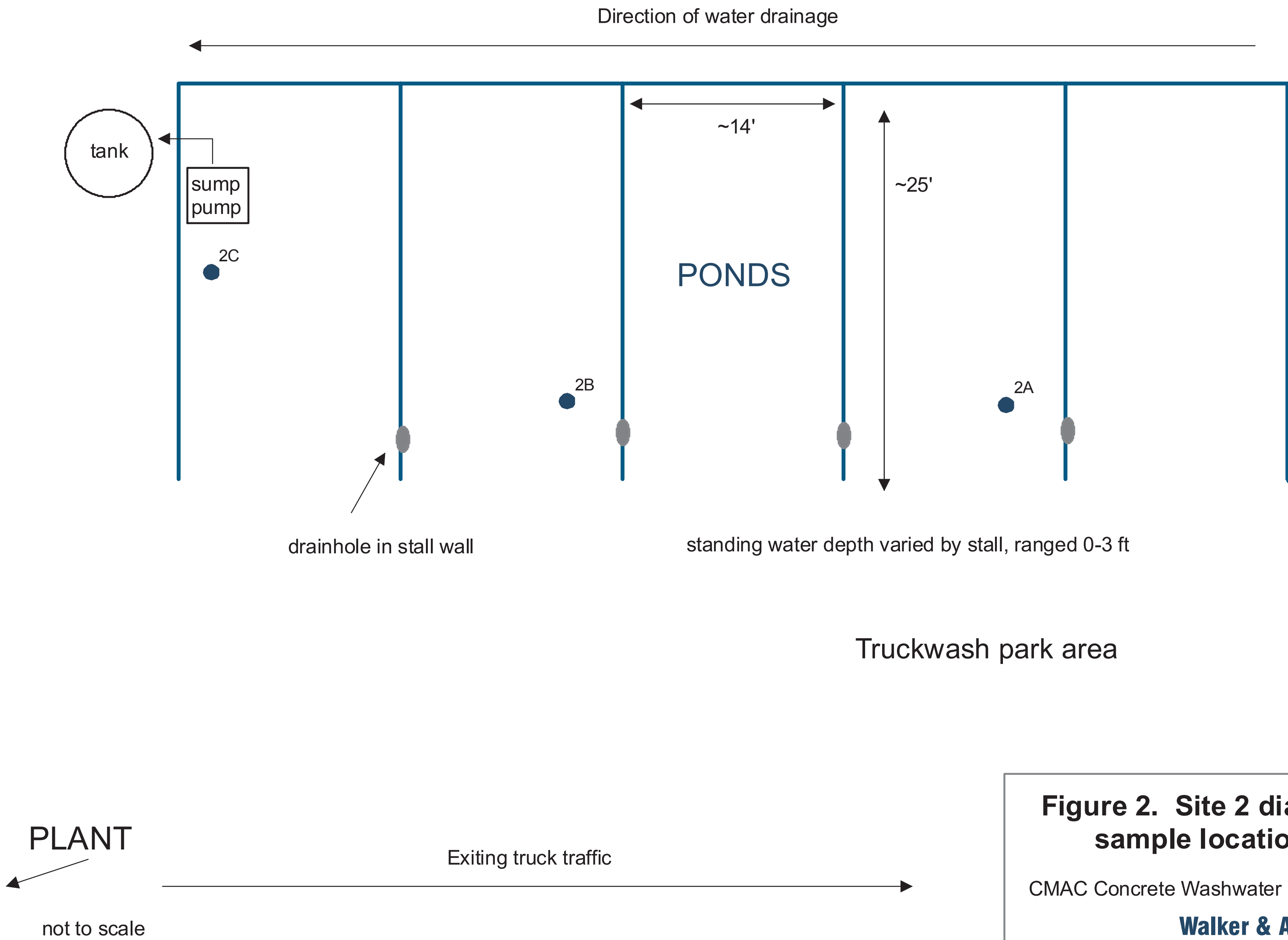
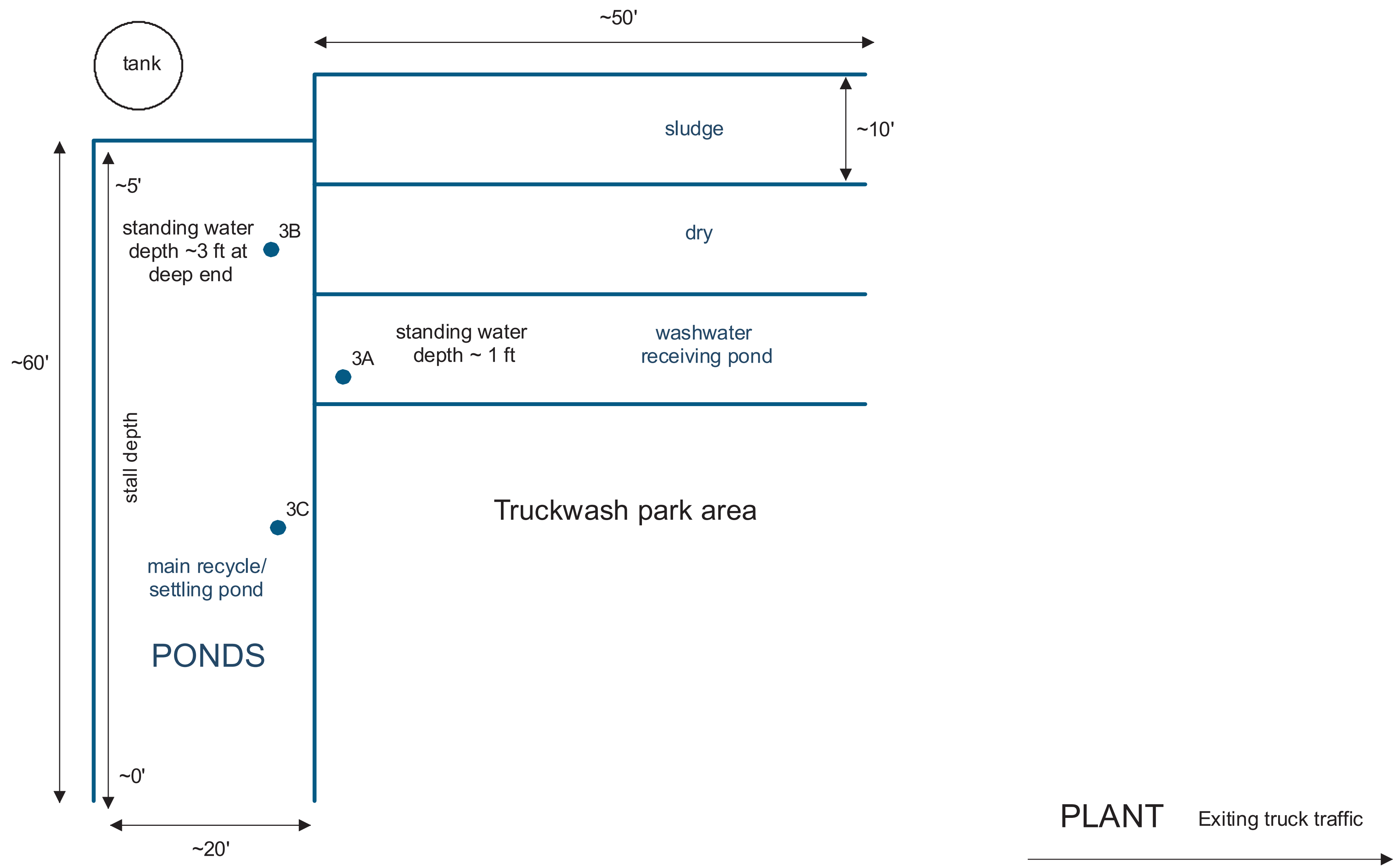


Figure 2. Site 2 diagram and sample locations 1/25/06

CMAC Concrete Washwater Pond Sampling

Walker & Associates



not to scale

Figure 3. Site 3 diagram and sample locations 1/25/06

CMAC Concrete Washwater Pond Sampling

Walker & Associates

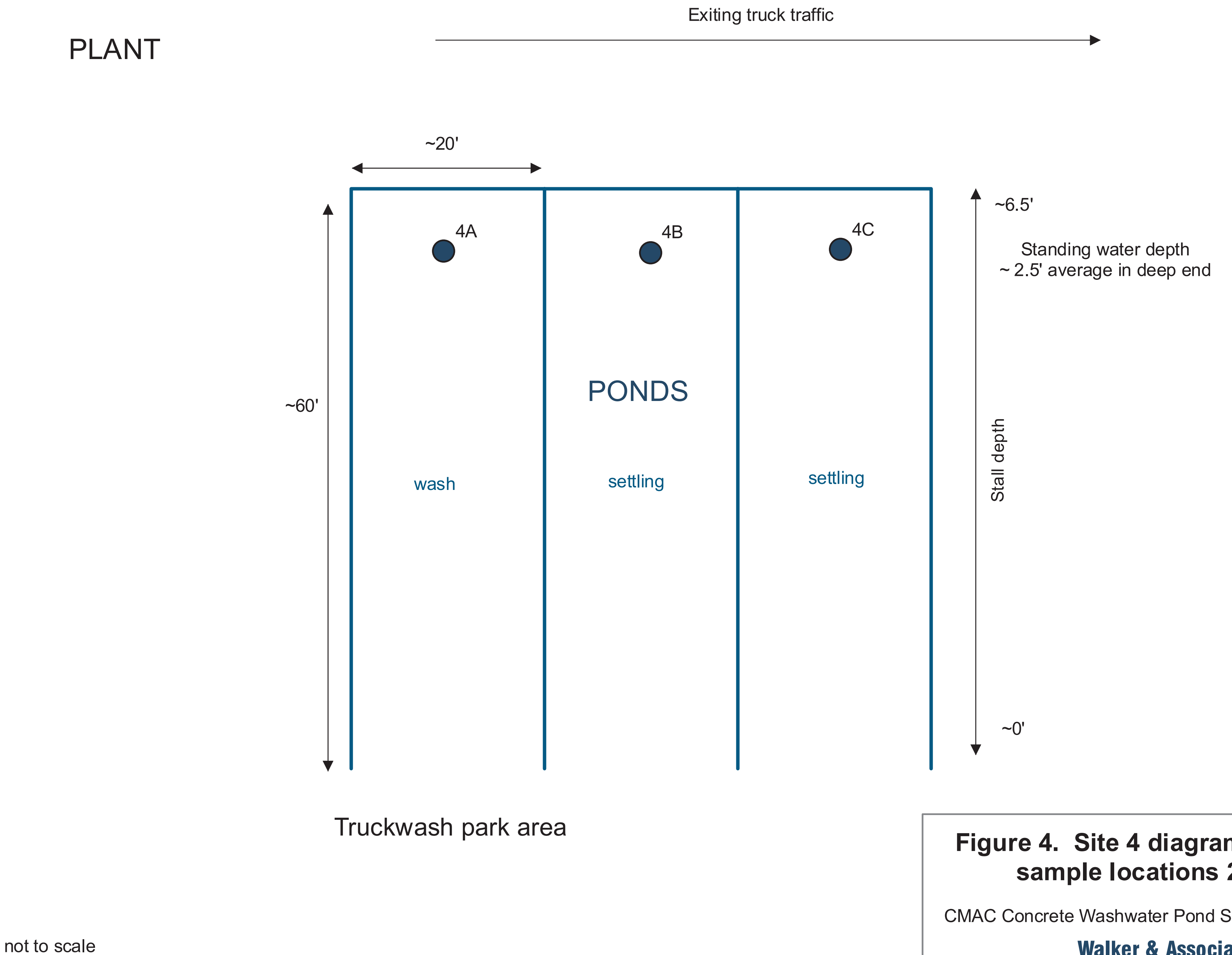


Figure 4. Site 4 diagram and sample locations 2/6/06

CMAC Concrete Washwater Pond Sampling

Walker & Associates

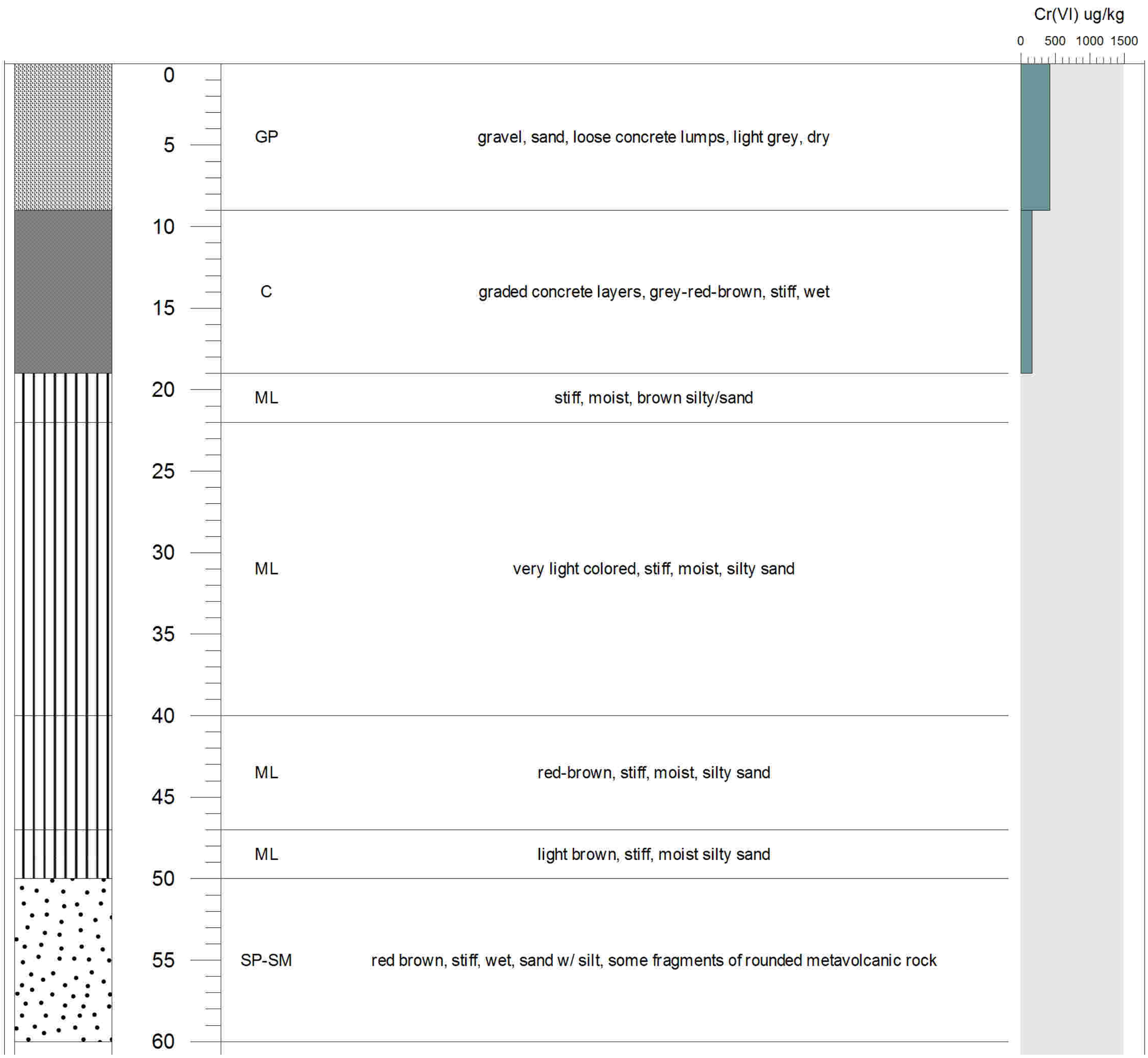
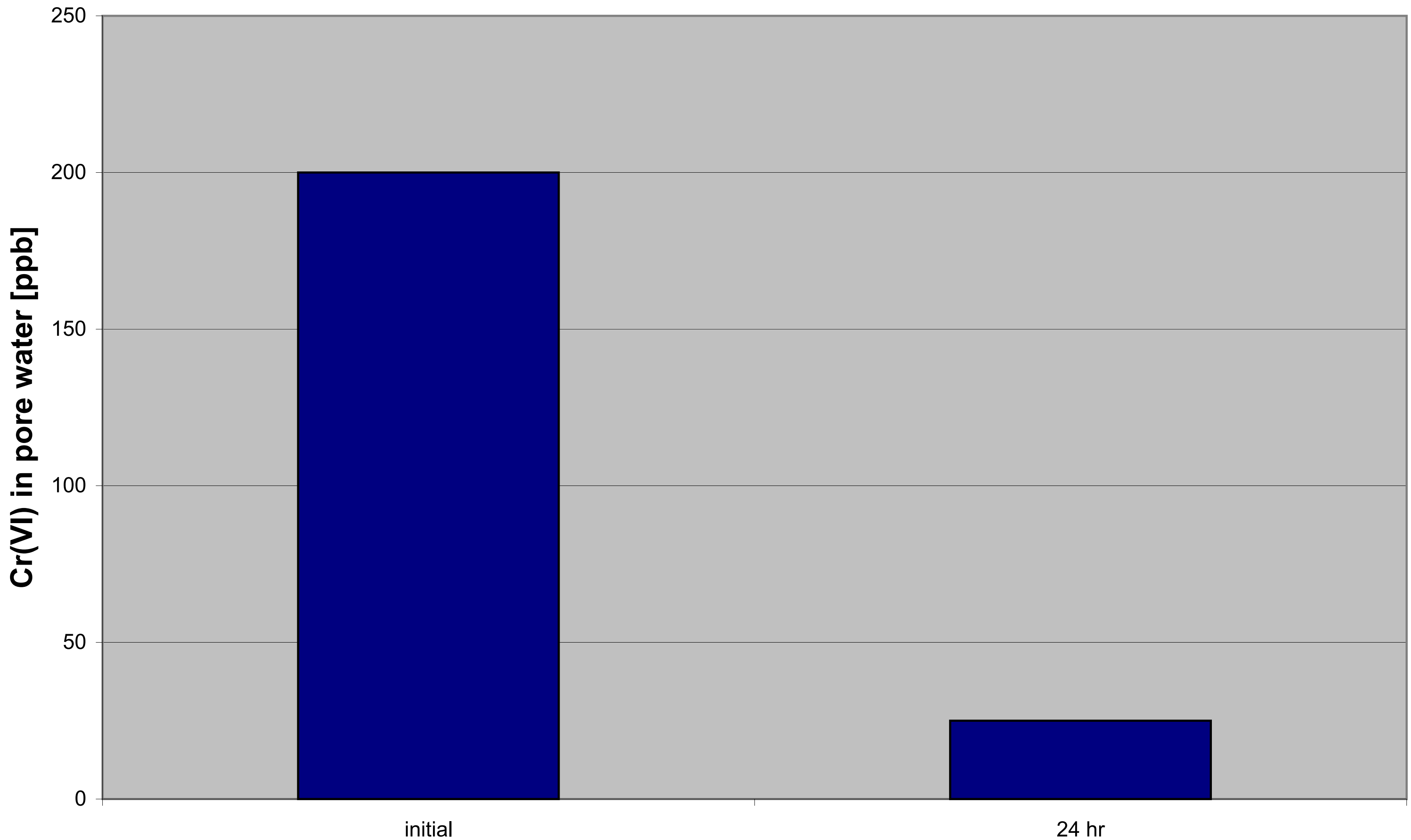


Figure 5. Sample boring log.

Figure 6. Results of bench-scale Cr(VI) attenuation test.



TABLES

Table 1. *Results of certified-lab analyses performed on site composite samples.*

		Site 1	Site 2	Site 3	Site 4
Bicarbonate as CaCO3	mg/L	<0.50	<0.50	<0.50	<0.50
Carbonate as CaCO3	mg/L	120	130	210	100
Hydroxide as CaCO3	mg/L	1100	450	1300	640
Total Alkalinity	mg/L	1200	580	1600	740
Arsenic	µg/L	350	<0.27	<0.27	<0.27
Lead	µg/L	180	<0.23	<0.23	<0.23
Selenium	µg/L	<1.1	<1.1	<1.1	<1.1
Thallium	µg/L	<0.11	<0.11	<0.11	<1.1
Antimony	µg/L	<41	<41	<41	<41
Barium	µg/L	420	230	830	1500
Beryllium	µg/L	<0.43	<0.43	<0.43	<0.43
Cadmium	µg/L	<2.8	<2.8	<2.8	<2.8
Chromium	µg/L	96	440	490	47
Cobalt	µg/L	<7.6	<7.6	<7.6	<7.6
Copper	µg/L	110	<3.2	30	<3.2
Molybdenum	µg/L	64	31	99	40
Nickel	µg/L	24	<14	<14	<14
Silver	µg/L	<2.9	<2.9	<2.9	<2.9
Vanadium	µg/L	63	<3.0	<3.0	<3.0
Zinc	µg/L	120	<9.2	<9.2	<9.2
Mercury	µg/L	<0.15	<0.15	<0.15	<0.15
Hexavalent Chromium	µg/L	76	460	540	39
Hexavalent Chromium, dissolved	µg/L	68	440	530	38
Aluminum, dissolved	µg/L	<27	58	<27	<27
Barium, dissolved	µg/L	210	220	780	1400
Boron, dissolved	µg/L	<4.4	78	<4.4	270
Calcium, dissolved	µg/L	410000	430000	710000	380000
Chromium, dissolved	µg/L	72	430	480	45
Iron, dissolved	µg/L	<6.8	200	<6.8	<6.8
Magnesium, dissolved	µg/L	<26	<26	<26	<26
Molybdenum, dissolved	µg/L	64	31	100	39
Potassium, dissolved	µg/L	28000	22000	85000	30000
Sodium, dissolved	µg/L	16000	48000	52000	92000
Vanadium, dissolved	µg/L	<3.0	<3.0	<3.0	<3.0
pH	pH Units	12.11	11.89	12.32	12.01
Total Dissolved Solids	mg/L	1300	1800	1900	1200
Specific Conductance (EC)	µmhos/cm	3500	3100	6100	3700
CLS Work Order		CPA0739	CPA0739	CPA0739	CPB0184
Sample Date		1/25/2006	1/25/2006	1/25/2006	2/6/2006

Relative Percent Difference limit for laboratory matrix spike duplicate QA/QC samples was 25%.

Table 2. *Results of in-field analysis (lab composite results shown for comparison).*

		pH*		Total Cr(VI) [ug/L]		
		Field	Lab	Field	Lab	Cr(VI) RPD**
Site 1	A	11.5		130		
	B	11.6		120		
	C	11.6		90		
	average			113		49%
	Composite		12.11		76	
Site 2	A	11.6		490		
	B	11.6		630		
	C	11.3		190		
	average			437		-5%
	Composite		11.89		460	
Site 3	A	12.0		590		
	B	11.9		340		
	C	11.9		310		
	average			413		-23%
	Composite		12.32		540	
Site 4	A	11.7		80		
	B	12.4		50		
	C	8.3		10		
	average			47		20%
	Composite		12.01		39	

*Field pH required special calibration using 3 points and a NIST pH 12.1 buffer to ensure accuracy. Laboratory measurements are not reliable due to 2 point calibration.

** Relative Percent Difference of average field value compared to lab composite measurement.

APPENDIX

LABORATORY RESULTS

CALIFORNIA LABORATORY SERVICES

3249 Fitzgerald Road Rancho Cordova, CA 95742

February 01, 2006

CLS Work Order #: CPA0739
COC #: 66514

Lara Christensen
Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project Name: CMAC

Enclosed are the results of analyses for samples received by the laboratory on 01/25/06 16:00. Samples were analyzed pursuant to client request utilizing EPA or other ELAP approved methodologies. I certify that the results are in compliance both technically and for completeness.

Analytical results are attached to this letter. Please call if we can provide additional assistance.

Sincerely,

James Liang, Ph.D.
Laboratory Director

CA DOHS ELAP Accreditation/Registration number 1233

CALIFORNIA LABORATORY SERVICES

02/01/06 11:26

Walker & Associates, Inc. 2618 J Street, Suite 1 Sacramento, CA 95816	Project: CMAC Project Number: [none] Project Manager: Lara Christensen	**CLS Work Order #: CPA0739** COC #: 66514

CLS - Labs

CHAIN OF CUSTODY — CLS ID No.: CPA0739 — LOG NO. 66514

REPORT TO:

NAME AND ADDRESS: Walker + Associates, 2618 J Street, Suite 1, Sacramento, CA 95816

PROJECT MANAGER: L.P. Christensen — PHONE# 916.442.5304

PROJECT NAME: CMAC

SAMPLED BY: LPC

JOB DESCRIPTION:

SITE LOCATION:

CLIENT JOB NUMBER:

DESTINATION LABORATORY: [X] CLS (916) 638-7301, 3249 FITZGERALD RD. RANCHO CORDOVA, CA. 95742 — [ ] OTHER

GEOTRACKER: EDF REPORT [ ] YES [ ] NO — GLOBAL ID:

COMPOSITE:

FIELD CONDITIONS:

DATE	TIME	SAMPLE IDENTIFICATION	MATRIX	CONTAINER NO.	CONTAINER TYPE	PRESERVATIVES	Composite A,B,C → single sample	pH, Alkalinity, TDS, Conductivity	Total Cr(VI) + Dis. Cr(VI) - 7199	Total CAM 17 - low DL	Dissolved Al, B, Ba, Ca, Cr, Fe, K, Mg, Mo, Na, V	TURN AROUND TIME: 1 DAY	2 DAY	5 DAY (Std)	10 DAY	SPECIAL INSTRUCTIONS OR ALT. ID:
1.25.06	10:51	1A	H_2O	1	1L poly	none	X									all analyses on
↓	10:55	1B	↓	↓	↓	↓	X	X	X	X	X			X		composite of
↓	10:58	1C	↓	↓	↓	↓	X									"A+B+C" for
																each location:
	12:50	2A	↓	↓	↓	↓	X									(1, 2, + 3)
↓	12:54	2B	↓	↓	↓	↓	X	X	X	X	X			X		(3 samples
↓	12:58	2C	↓	↓	↓	↓	X									total to analyze)
	15:00	3A	↓	↓	↓	↓	X									INVOICE TO:
↓	15:04	3B	↓	↓	↓	↓	X	X	X	X	X			X		
↓	15:10	3C	↓	↓	↓	↓	X									
																P.O. #
																QUOTE #

SUSPECTED CONSTITUENTS:

PRESERVATIVES: (1) HCL (2) HNO_3 (3) = COLD (4) = NaOH (5) = H_2SO_4 (6) = $Na_2S_2O_3$ (7) =

RELINQUISHED BY (SIGN)	PRINT NAME / COMPANY	DATE / TIME	RECEIVED BY (SIGN)	PRINT NAME / COMPANY
Lara Pucik Christensen	LARA PUCIK CHRISTENSEN / WAI	1.25.06 16:00		

REC'D AT LAB BY: Jon R — DATE / TIME: 1-25-6 1600 — CONDITIONS / COMMENTS:

SHIPPED BY: [ ] FED X [ ] UPS [ ] OTHER ______ AIR BILL #

LAB

CALIFORNIA LABORATORY SERVICES

02/01/06 11:26

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPA0739
COC #: 66514

CAM 17 Metals

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Composite 1A-1C (CPA0739-04) Water	**Sampled: 01/25/06 00:00**		**Received: 01/25/06 16:00**						
Arsenic	**350**	25	µg/L	5	CP00589	01/26/06	01/26/06	EPA 200.8	
Lead	**180**	5.0	"	1	"	"	"	"	
Selenium	ND	5.0	"	"	"	"	"	"	
Thallium	ND	10	"	"	"	"	"	"	
Antimony	ND	50	"	"	CP00594	01/26/06	01/26/06	EPA 200.7	
Barium	**420**	20	"	"	"	"	"	"	
Beryllium	ND	5.0	"	"	"	"	"	"	
Cadmium	ND	10	"	"	"	"	"	"	
Cobalt	ND	20	"	"	"	"	"	"	
Chromium	**96**	20	"	"	"	"	"	"	
Copper	**110**	20	"	"	"	"	"	"	
Molybdenum	**64**	20	"	"	"	"	"	"	
Nickel	**24**	20	"	"	"	"	"	"	
Silver	ND	10	"	"	"	"	"	"	
Vanadium	**63**	20	"	"	"	"	"	"	
Zinc	**120**	20	"	"	"	"	"	"	
Mercury	ND	0.20	"	"	CP00598	01/26/06	01/27/06	EPA 245.1	
Composite 2A-2C (CPA0739-08) Water	**Sampled: 01/25/06 00:00**		**Received: 01/25/06 16:00**						
Arsenic	ND	5.0	µg/L	1	CP00589	01/26/06	01/26/06	EPA 200.8	
Lead	ND	5.0	"	"	"	"	"	"	
Selenium	ND	5.0	"	"	"	"	"	"	
Thallium	ND	10	"	"	"	"	"	"	
Antimony	ND	50	"	"	CP00594	01/26/06	01/26/06	EPA 200.7	
Barium	**230**	20	"	"	"	"	"	"	
Beryllium	ND	5.0	"	"	"	"	"	"	
Cadmium	ND	10	"	"	"	"	"	"	
Cobalt	ND	20	"	"	"	"	"	"	
Chromium	**440**	20	"	"	"	"	"	"	
Copper	ND	20	"	"	"	"	"	"	
Molybdenum	**31**	20	"	"	"	"	"	"	
Nickel	ND	20	"	"	"	"	"	"	
Silver	ND	10	"	"	"	"	"	"	
Vanadium	ND	20	"	"	"	"	"	"	
Zinc	ND	20	"	"	"	"	"	"	

CALIFORNIA LABORATORY SERVICES

02/01/06 11:26

Walker & Associates, Inc.	Project: CMAC	
2618 J Street, Suite 1	Project Number: [none]	**CLS Work Order #: CPA0739**
Sacramento, CA 95816	Project Manager: Lara Christensen	COC #: 66514

CAM 17 Metals

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Composite 2A-2C (CPA0739-08) Water	**Sampled: 01/25/06 00:00**		**Received: 01/25/06 16:00**						
Mercury	ND	0.20	µg/L	1	CP00598	01/26/06	01/27/06	EPA 245.1	
Composite 3A-3C (CPA0739-12) Water	**Sampled: 01/25/06 00:00**		**Received: 01/25/06 16:00**						
Arsenic	ND	5.0	µg/L	1	CP00589	01/26/06	01/26/06	EPA 200.8	
Lead	ND	5.0	"	"	"	"	"	"	
Selenium	ND	5.0	"	"	"	"	"	"	
Thallium	ND	10	"	"	"	"	"	"	
Antimony	ND	50	"	"	CP00594	01/26/06	01/26/06	EPA 200.7	
Barium	**830**	20	"	"	"	"	"	"	
Beryllium	ND	5.0	"	"	"	"	"	"	
Cadmium	ND	10	"	"	"	"	"	"	
Cobalt	ND	20	"	"	"	"	"	"	
Chromium	**490**	20	"	"	"	"	"	"	
Copper	**30**	20	"	"	"	"	"	"	
Molybdenum	**99**	20	"	"	"	"	"	"	
Nickel	ND	20	"	"	"	"	"	"	
Silver	ND	10	"	"	"	"	"	"	
Vanadium	ND	20	"	"	"	"	"	"	
Zinc	ND	20	"	"	"	"	"	"	
Mercury	ND	0.20	"	"	CP00598	01/26/06	01/27/06	EPA 245.1	

CALIFORNIA LABORATORY SERVICES

02/01/06 11:26

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPA0739
COC #: 66514

Conventional Chemistry Parameters by APHA/EPA Methods

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Composite 1A-1C (CPA0739-04) Water	**Sampled: 01/25/06 00:00**		**Received: 01/25/06 16:00**						
Total Alkalinity	**1200**	5.0	mg/L	1	CP00603	01/26/06	01/26/06	EPA 310.1	
Bicarbonate as CaCO3	ND	5.0	"	"	"	"	"	"	
Carbonate as CaCO3	**120**	5.0	"	"	"	"	"	"	
Hydroxide as CaCO3	**1100**	5.0	"	"	"	"	"	"	
Specific Conductance (EC)	**3500**	1.0	µmhos/cm	"	CP00644	01/27/06	01/27/06	EPA 120.1	
Hexavalent Chromium	**76**	5.0	µg/L	5	CP00584	01/26/06	01/26/06	EPA 7199	
Hexavalent Chromium, Dissolved	**68**	5.0	"	"	"	"	"	"	
pH	**12.11**		pH Units	1	CP00580	"	"	EPA 150.1	
Total Dissolved Solids	**1300**	10	mg/L	"	CP00592	01/26/06	01/26/06	EPA 160.1	
Composite 2A-2C (CPA0739-08) Water	**Sampled: 01/25/06 00:00**		**Received: 01/25/06 16:00**						
Total Alkalinity	**580**	5.0	mg/L	1	CP00603	01/26/06	01/26/06	EPA 310.1	
Bicarbonate as CaCO3	ND	5.0	"	"	"	"	"	"	
Carbonate as CaCO3	**130**	5.0	"	"	"	"	"	"	
Hydroxide as CaCO3	**450**	5.0	"	"	"	"	"	"	
Specific Conductance (EC)	**3100**	1.0	µmhos/cm	"	CP00644	01/27/06	01/27/06	EPA 120.1	
Hexavalent Chromium	**460**	20	µg/L	20	CP00584	01/26/06	01/26/06	EPA 7199	
Hexavalent Chromium, Dissolved	**440**	20	"	"	"	"	"	"	
pH	**11.89**		pH Units	1	CP00580	"	"	EPA 150.1	
Total Dissolved Solids	**1800**	10	mg/L	"	CP00592	01/26/06	01/26/06	EPA 160.1	
Composite 3A-3C (CPA0739-12) Water	**Sampled: 01/25/06 00:00**		**Received: 01/25/06 16:00**						
Total Alkalinity	**1600**	5.0	mg/L	1	CP00603	01/26/06	01/26/06	EPA 310.1	
Bicarbonate as CaCO3	ND	5.0	"	"	"	"	"	"	
Carbonate as CaCO3	**210**	5.0	"	"	"	"	"	"	
Hydroxide as CaCO3	**1300**	5.0	"	"	"	"	"	"	
Specific Conductance (EC)	**6100**	1.0	µmhos/cm	"	CP00644	01/27/06	01/27/06	EPA 120.1	
Hexavalent Chromium	**540**	20	µg/L	20	CP00584	01/26/06	01/26/06	EPA 7199	
Hexavalent Chromium, Dissolved	**530**	20	"	"	"	"	"	"	
pH	**12.32**		pH Units	1	CP00580	"	"	EPA 150.1	
Total Dissolved Solids	**1900**	10	mg/L	"	CP00592	01/26/06	01/26/06	EPA 160.1	

CALIFORNIA LABORATORY SERVICES

02/01/06 11:26

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPA0739
COC #: 66514

Metals (Dissolved) by EPA 200 Series Methods

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Composite 1A-1C (CPA0739-04) Water	**Sampled: 01/25/06 00:00**		**Received: 01/25/06 16:00**						
Aluminum	ND	50	µg/L	1	CP00594	01/26/06	01/26/06	EPA 200.7	
Barium	**210**	20	"	"	"	"	"	"	
Calcium	**410000**	1000	"	"	"	"	"	"	
Chromium	**72**	10	"	"	"	"	"	"	
Iron	ND	100	"	"	"	"	"	"	
Magnesium	ND	1000	"	"	"	"	"	"	
Molybdenum	**64**	20	"	"	"	"	"	"	
Potassium	**28000**	1000	"	"	"	"	"	"	
Sodium	**16000**	1000	"	"	"	"	"	"	
Vanadium	ND	20	"	"	"	"	"	"	
Boron	ND	50	"	"	"	"	"	"	
Composite 2A-2C (CPA0739-08) Water	**Sampled: 01/25/06 00:00**		**Received: 01/25/06 16:00**						
Aluminum	**58**	50	µg/L	1	CP00594	01/26/06	01/26/06	EPA 200.7	
Barium	**220**	20	"	"	"	"	"	"	
Calcium	**430000**	1000	"	"	"	"	"	"	
Chromium	**430**	10	"	"	"	"	"	"	
Iron	**200**	100	"	"	"	"	"	"	
Magnesium	ND	1000	"	"	"	"	"	"	
Molybdenum	**31**	20	"	"	"	"	"	"	
Potassium	**22000**	1000	"	"	"	"	"	"	
Sodium	**48000**	1000	"	"	"	"	"	"	
Vanadium	ND	20	"	"	"	"	"	"	
Boron	**78**	50	"	"	"	"	"	"	

Walker & Associates, Inc.
2618 J Street, Suite 1
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Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPA0739
COC #: 66514

Metals (Dissolved) by EPA 200 Series Methods

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Composite 3A-3C (CPA0739-12) Water	**Sampled: 01/25/06 00:00**		**Received: 01/25/06 16:00**						
Aluminum	ND	50	µg/L	1	CP00594	01/26/06	01/26/06	EPA 200.7	
Barium	**780**	20	"	"	"	"	"	"	
Calcium	**710000**	5000	"	5	"	"	"	"	
Chromium	**480**	10	"	1	"	"	"	"	
Iron	ND	100	"	"	"	"	"	"	
Magnesium	ND	1000	"	"	"	"	"	"	
Molybdenum	**100**	20	"	"	"	"	"	"	
Potassium	**85000**	1000	"	"	"	"	"	"	
Sodium	**52000**	1000	"	"	"	"	"	"	
Vanadium	ND	20	"	"	"	"	"	"	
Boron	ND	50	"	"	"	"	"	"	

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPA0739
COC #: 66514

CAM 17 Metals - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00589 - EPA 3020A										
Blank (CP00589-BLK1)				Prepared & Analyzed: 01/26/06						
Arsenic	ND	5.0	µg/L							
Lead	ND	5.0	"							
Selenium	ND	5.0	"							
Thallium	ND	10	"							
LCS (CP00589-BS1)				Prepared & Analyzed: 01/26/06						
Arsenic	103	5.0	µg/L	100		103	80-120			
Lead	103	5.0	"	100		103	80-120			
Selenium	107	5.0	"	100		107	80-120			
Thallium	104	10	"	100		104	80-120			
LCS Dup (CP00589-BSD1)				Prepared & Analyzed: 01/26/06						
Arsenic	96.1	5.0	µg/L	100		96.1	80-120	6.93	20	
Lead	101	5.0	"	100		101	80-120	1.96	20	
Selenium	101	5.0	"	100		101	80-120	5.77	20	
Thallium	101	10	"	100		101	80-120	2.93	20	
Matrix Spike (CP00589-MS1)		**Source: CPA0744-02**		Prepared & Analyzed: 01/26/06						
Arsenic	127	5.0	µg/L	100	9.4	118	75-125			
Lead	108	5.0	"	100	0.31	108	75-125			
Selenium	124	5.0	"	100	9.3	115	75-125			
Thallium	112	10	"	100	0.19	112	75-125			
Matrix Spike Dup (CP00589-MSD1)		**Source: CPA0744-02**		Prepared & Analyzed: 01/26/06						
Arsenic	117	5.0	µg/L	100	9.4	108	75-125	8.20	25	
Lead	97.2	5.0	"	100	0.31	96.9	75-125	10.5	25	
Selenium	113	5.0	"	100	9.3	104	75-125	9.28	25	
Thallium	101	10	"	100	0.19	101	75-125	10.3	25	

CALIFORNIA LABORATORY SERVICES

02/01/06 11:26

Walker & Associates, Inc. 2618 J Street, Suite 1 Sacramento, CA 95816	Project: CMAC Project Number: [none] Project Manager: Lara Christensen	**CLS Work Order #: CPA0739** COC #: 66514

CAM 17 Metals - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00594 - EPA 3010A										
Blank (CP00594-BLK1)				Prepared & Analyzed: 01/26/06						
Antimony	ND	50	µg/L							
Barium	ND	20	"							
Beryllium	ND	5.0	"							
Cadmium	ND	10	"							
Cobalt	ND	20	"							
Chromium	ND	20	"							
Copper	ND	20	"							
Molybdenum	ND	20	"							
Nickel	ND	20	"							
Silver	ND	10	"							
Vanadium	ND	20	"							
Zinc	ND	20	"							
LCS (CP00594-BS1)				Prepared & Analyzed: 01/26/06						
Antimony	539	50	µg/L	500		108	80-120			
Barium	2070	20	"	2000		104	80-120			
Beryllium	53.5	5.0	"	50.0		107	80-120			
Cadmium	58.3	10	"	50.0		117	80-120			
Cobalt	533	20	"	500		107	80-120			
Chromium	215	20	"	200		108	80-120			
Copper	259	20	"	250		104	80-120			
Molybdenum	538	20	"	500		108	80-120			
Nickel	527	20	"	500		105	80-120			
Silver	50.2	10	"	50.0		100	80-120			
Vanadium	528	20	"	500		106	80-120			
Zinc	531	20	"	500		106	80-120			
LCS Dup (CP00594-BSD1)				Prepared & Analyzed: 01/26/06						
Antimony	538	50	µg/L	500		108	80-120	0.186	20	
Barium	2080	20	"	2000		104	80-120	0.482	20	
Beryllium	53.7	5.0	"	50.0		107	80-120	0.373	20	
Cadmium	57.2	10	"	50.0		114	80-120	1.90	20	

CALIFORNIA LABORATORY SERVICES

Walker & Associates, Inc.	Project: CMAC	
2618 J Street, Suite 1	Project Number: [none]	**CLS Work Order #: CPA0739**
Sacramento, CA 95816	Project Manager: Lara Christensen	COC #: 66514

CAM 17 Metals - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00594 - EPA 3010A										
LCS Dup (CP00594-BSD1)				Prepared & Analyzed: 01/26/06						
Cobalt	539	20	µg/L	500		108	80-120	1.12	20	
Chromium	221	20	"	200		110	80-120	2.75	20	
Copper	261	20	"	250		104	80-120	0.769	20	
Molybdenum	545	20	"	500		109	80-120	1.29	20	
Nickel	529	20	"	500		106	80-120	0.379	20	
Silver	54.6	10	"	50.0		109	80-120	8.40	20	
Vanadium	532	20	"	500		106	80-120	0.755	20	
Zinc	531	20	"	500		106	80-120	0.00	20	
Matrix Spike (CP00594-MS1)		**Source: CPA0744-02**		Prepared & Analyzed: 01/26/06						
Antimony	540	50	µg/L	500	ND	108	75-125			
Barium	2130	20	"	2000	71	103	75-125			
Beryllium	52.7	5.0	"	50.0	ND	105	75-125			
Cadmium	59.5	10	"	50.0	ND	119	75-125			
Cobalt	514	20	"	500	ND	103	75-125			
Chromium	231	20	"	200	ND	116	75-125			
Copper	260	20	"	250	ND	104	75-125			
Molybdenum	537	20	"	500	10	105	75-125			
Nickel	506	20	"	500	ND	101	75-125			
Silver	51.0	10	"	50.0	ND	102	75-125			
Vanadium	556	20	"	500	35	104	75-125			
Zinc	515	20	"	500	ND	103	75-125			
Matrix Spike Dup (CP00594-MSD1)		**Source: CPA0744-02**		Prepared & Analyzed: 01/26/06						
Antimony	547	50	µg/L	500	ND	109	75-125	1.29	25	
Barium	2110	20	"	2000	71	102	75-125	0.943	25	
Beryllium	52.6	5.0	"	50.0	ND	105	75-125	0.190	25	
Cadmium	53.8	10	"	50.0	ND	108	75-125	10.1	25	
Cobalt	511	20	"	500	ND	102	75-125	0.585	25	
Chromium	224	20	"	200	ND	112	75-125	3.08	25	
Copper	257	20	"	250	ND	103	75-125	1.16	25	
Molybdenum	536	20	"	500	10	105	75-125	0.186	25	

CALIFORNIA LABORATORY SERVICES

 02/01/06 11:26

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPA0739
COC #: 66514

CAM 17 Metals - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00594 - EPA 3010A										
Matrix Spike Dup (CP00594-MSD1)	**Source: CPA0744-02**			Prepared & Analyzed: 01/26/06						
Nickel	501	20	µg/L	500	ND	100	75-125	0.993	25	
Silver	48.3	10	"	50.0	ND	96.6	75-125	5.44	25	
Vanadium	552	20	"	500	35	103	75-125	0.722	25	
Zinc	514	20	"	500	ND	103	75-125	0.194	25	
Batch CP00598 - EPA 7470A										
Blank (CP00598-BLK1)				Prepared: 01/26/06 Analyzed: 01/27/06						
Mercury	ND	0.20	µg/L							
LCS (CP00598-BS1)				Prepared: 01/26/06 Analyzed: 01/27/06						
Mercury	4.90	0.20	µg/L	5.00		98.0	75-125			
LCS Dup (CP00598-BSD1)				Prepared: 01/26/06 Analyzed: 01/27/06						
Mercury	5.02	0.20	µg/L	5.00		100	75-125	2.42	25	
Matrix Spike (CP00598-MS1)	**Source: CPA0724-01**			Prepared: 01/26/06 Analyzed: 01/27/06						
Mercury	5.36	0.20	µg/L	5.00	ND	107	75-125			
Matrix Spike Dup (CP00598-MSD1)	**Source: CPA0724-01**			Prepared: 01/26/06 Analyzed: 01/27/06						
Mercury	4.91	0.20	µg/L	5.00	ND	98.2	75-125	8.76	25	

CALIFORNIA LABORATORY SERVICES

02/01/06 11:26

Walker & Associates, Inc.	Project: CMAC	
2618 J Street, Suite 1	Project Number: [none]	**CLS Work Order #: CPA0739**
Sacramento, CA 95816	Project Manager: Lara Christensen	COC #: 66514

Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00584 - General Prep										
Blank (CP00584-BLK1)				Prepared & Analyzed: 01/26/06						
Hexavalent Chromium	ND	1.0	µg/L							
Hexavalent Chromium, Dissolved	ND	1.0	"							
LCS (CP00584-BS1)				Prepared & Analyzed: 01/26/06						
Hexavalent Chromium	4.92	1.0	µg/L	5.00		98.4	80-120			
Hexavalent Chromium, Dissolved	4.92	1.0	"	5.00		98.4	80-120			
LCS Dup (CP00584-BSD1)				Prepared & Analyzed: 01/26/06						
Hexavalent Chromium	5.13	1.0	µg/L	5.00		103	80-120	4.18	20	
Hexavalent Chromium, Dissolved	5.13	1.0	"	5.00		103	80-120	4.18	20	
Matrix Spike (CP00584-MS1)	**Source: CPA0724-01**			Prepared & Analyzed: 01/26/06						
Hexavalent Chromium	5.80	1.0	µg/L	5.00	ND	116	75-125			
Hexavalent Chromium, Dissolved	5.80	1.0	"	5.00	ND	116	75-125			
Matrix Spike Dup (CP00584-MSD1)	**Source: CPA0724-01**			Prepared & Analyzed: 01/26/06						
Hexavalent Chromium	5.32	1.0	µg/L	5.00	ND	106	75-125	8.63	25	
Hexavalent Chromium, Dissolved	5.32	1.0	"	5.00	ND	106	75-125	8.63	25	
Batch CP00592 - General Preparation										
Blank (CP00592-BLK1)				Prepared & Analyzed: 01/26/06						
Total Dissolved Solids	ND	10	mg/L							
Batch CP00603 - General Preparation										
Blank (CP00603-BLK1)				Prepared & Analyzed: 01/26/06						
Total Alkalinity	ND	5.0	mg/L							
Bicarbonate as CaCO3	ND	5.0	"							
Carbonate as CaCO3	ND	5.0	"							
Hydroxide as CaCO3	ND	5.0	"							

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPA0739
COC #: 66514

Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00644 - General Preparation										
Blank (CP00644-BLK1)				Prepared & Analyzed: 01/27/06						
Specific Conductance (EC)	ND	1.0	µmhos/cm							

CALIFORNIA LABORATORY SERVICES

Walker & Associates, Inc. 2618 J Street, Suite 1 Sacramento, CA 95816	Project: CMAC Project Number: [none] Project Manager: Lara Christensen	**CLS Work Order #: CPA0739** COC #: 66514

Metals (Dissolved) by EPA 200 Series Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00594 - EPA 3010A										
Blank (CP00594-BLK1)				Prepared & Analyzed: 01/26/06						
Aluminum	ND	50	µg/L							
Barium	ND	20	"							
Calcium	ND	1000	"							
Chromium	ND	10	"							
Copper	ND	10	"							
Iron	ND	100	"							
Magnesium	ND	1000	"							
Manganese	ND	20	"							
Molybdenum	ND	20	"							
Nickel	ND	20	"							
Potassium	ND	1000	"							
Sodium	ND	1000	"							
Vanadium	ND	20	"							
Zinc	ND	20	"							
Boron	ND	50	"							
LCS (CP00594-BS1)				Prepared & Analyzed: 01/26/06						
Aluminum	2080	50	µg/L	2000		104	80-120			
Barium	2070	20	"	2000		104	80-120			
Calcium	10400	1000	"	10000		104	80-120			
Chromium	215	10	"	200		108	80-120			
Copper	259	10	"	250		104	80-120			
Iron	1020	100	"	1000		102	80-120			
Magnesium	10400	1000	"	10000		104	80-120			
Manganese	528	20	"	500		106	80-120			
Molybdenum	538	20	"	500		108	80-120			
Nickel	527	20	"	500		105	80-120			
Potassium	10000	1000	"	10000		100	80-120			
Sodium	10400	1000	"	10000		104	80-120			
Vanadium	528	20	"	500		106	80-120			
Zinc	531	20	"	500		106	80-120			

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPA0739
COC #: 66514

Metals (Dissolved) by EPA 200 Series Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00594 - EPA 3010A										
LCS (CP00594-BS1)				Prepared & Analyzed: 01/26/06						
Boron	2580	50	µg/L	2500		103	80-120			
LCS Dup (CP00594-BSD1)				Prepared & Analyzed: 01/26/06						
Aluminum	2080	50	µg/L	2000		104	80-120	0.00	20	
Barium	2080	20	"	2000		104	80-120	0.482	20	
Calcium	10400	1000	"	10000		104	80-120	0.00	20	
Chromium	221	10	"	200		110	80-120	2.75	20	
Copper	261	10	"	250		104	80-120	0.769	20	
Iron	1040	100	"	1000		104	80-120	1.94	20	
Magnesium	10500	1000	"	10000		105	80-120	0.957	20	
Manganese	530	20	"	500		106	80-120	0.378	20	
Molybdenum	545	20	"	500		109	80-120	1.29	20	
Nickel	529	20	"	500		106	80-120	0.379	20	
Potassium	9950	1000	"	10000		99.5	80-120	0.501	20	
Sodium	10400	1000	"	10000		104	80-120	0.00	20	
Vanadium	532	20	"	500		106	80-120	0.755	20	
Zinc	531	20	"	500		106	80-120	0.00	20	
Boron	2600	50	"	2500		104	80-120	0.772	20	
Matrix Spike (CP00594-MS1)		**Source: CPA0744-02**		Prepared & Analyzed: 01/26/06						
Aluminum	2080	50	µg/L	2000	ND	104	75-125			
Barium	2130	20	"	2000	71	103	75-125			
Calcium	60600	1000	"	10000	50000	106	75-125			
Chromium	231	10	"	200	ND	116	75-125			
Copper	260	10	"	250	ND	104	75-125			
Iron	1010	100	"	1000	ND	101	75-125			
Magnesium	36500	1000	"	10000	26000	105	75-125			
Manganese	510	20	"	500	ND	102	75-125			
Molybdenum	537	20	"	500	10	105	75-125			
Nickel	506	20	"	500	ND	101	75-125			
Potassium	13800	1000	"	10000	3600	102	75-125			
Sodium	364000	1000	"	10000	350000	140	75-125			QM-4X

CALIFORNIA LABORATORY SERVICES

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPA0739
COC #: 66514

Metals (Dissolved) by EPA 200 Series Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00594 - EPA 3010A										
Matrix Spike (CP00594-MS1)		**Source: CPA0744-02**		Prepared & Analyzed: 01/26/06						
Vanadium	556	20	µg/L	500	35	104	75-125			
Zinc	515	20	"	500	ND	103	75-125			
Boron	3520	50	"	2500	970	102	75-125			
Matrix Spike Dup (CP00594-MSD1)		**Source: CPA0744-02**		Prepared & Analyzed: 01/26/06						
Aluminum	2060	50	µg/L	2000	ND	103	75-125	0.966	25	
Barium	2110	20	"	2000	71	102	75-125	0.943	25	
Calcium	60300	1000	"	10000	50000	103	75-125	0.496	25	
Chromium	224	10	"	200	ND	112	75-125	3.08	25	
Copper	257	10	"	250	ND	103	75-125	1.16	25	
Iron	1000	100	"	1000	ND	100	75-125	0.995	25	
Magnesium	36300	1000	"	10000	26000	103	75-125	0.549	25	
Manganese	506	20	"	500	ND	101	75-125	0.787	25	
Molybdenum	536	20	"	500	10	105	75-125	0.186	25	
Nickel	501	20	"	500	ND	100	75-125	0.993	25	
Potassium	13700	1000	"	10000	3600	101	75-125	0.727	25	
Sodium	361000	1000	"	10000	350000	110	75-125	0.828	25	
Vanadium	552	20	"	500	35	103	75-125	0.722	25	
Zinc	514	20	"	500	ND	103	75-125	0.194	25	
Boron	3500	50	"	2500	970	101	75-125	0.570	25	

Walker & Associates, Inc.	Project: CMAC	
2618 J Street, Suite 1	Project Number: [none]	**CLS Work Order #: CPA0739**
Sacramento, CA 95816	Project Manager: Lara Christensen	COC #: 66514

Notes and Definitions

QM-4X	The spike recovery was outside of QC acceptance limits for the MS and/or MSD due to analyte concentration at 4 times or greater the spike concentration. The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.
DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference

CALIFORNIA LABORATORY SERVICES

3249 Fitzgerald Road Rancho Cordova, CA 95742

February 15, 2006

CLS Work Order #: CPB0184
COC #: 69199

Lara Christensen
Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project Name: CMAC

Enclosed are the results of analyses for samples received by the laboratory on 02/06/06 15:45. Samples were analyzed pursuant to client request utilizing EPA or other ELAP approved methodologies. I certify that the results are in compliance both technically and for completeness.

Analytical results are attached to this letter. Please call if we can provide additional assistance.

Sincerely,

James Liang, Ph.D.
Laboratory Director

CA DOHS ELAP Accreditation/Registration number 1233

CALIFORNIA LABORATORY SERVICES

02/15/06 12:54

Walker & Associates, Inc. 2618 J Street, Suite 1 Sacramento, CA 95816	Project: CMAC Project Number: [none] Project Manager: Lara Christensen	**CLS Work Order #: CPB0184** COC #: 69199

CLS - Labs CHAIN OF CUSTODY CLS ID No.: CPB0184 LOG NO. 69199

REPORT TO:
NAME AND ADDRESS: Walker + Associates, 2618 J Street Suite 1, Sacramento CA 95816
PROJECT MANAGER: L.P. Christensen PHONE#: 916.442.5304
PROJECT NAME: CMAC
SAMPLED BY: LPC
JOB DESCRIPTION:
SITE LOCATION:

CLIENT JOB NUMBER:

DESTINATION LABORATORY: [X] CLS (916) 638-7301, 3249 FITZGERALD RD., RANCHO CORDOVA, CA. 95742 ☐ OTHER

ANALYSIS REQUESTED: Composite ABC → single sample; pH, Alkalinity, TDS, Conductivity; Total Cr(VI) 7199, Diss. Cr(VI) 7199; Total CAM 17 - low DL; Dissolved Al, B, Ba, Ca, Cr, Fe, K, Mg, Mo, Na, V

GEOTRACKER: EDF REPORT ☐ YES ☐ NO
GLOBAL ID:
COMPOSITE:
FIELD CONDITIONS:

TURN AROUND TIME: 1 DAY, 2 DAY, (5 DAY) Std, 10 DAY

DATE	TIME	SAMPLE IDENTIFICATION	MATRIX	CONTAINER NO.	CONTAINER TYPE	PRESERVATIVES	Composite ABC	pH, Alk., TDS, Cond.	Total Cr(VI), Diss. Cr(VI)	Total CAM 17	Dissolved metals
2.6.06	12:48	4A	H_2O	1	1L poly	none	X				
	12:53	4B	↓	↓	↓	↓	X	X	X X	X	X
	12:56	4C	↓	↓	↓	↓	X				

SPECIAL INSTRUCTIONS OR ALT. ID: all analyses on composite of A + B + C 3:1 Composite

INVOICE TO:
P.O. #
QUOTE #

SUSPECTED CONSTITUENTS:
PRESERVATIVES: (1) HCL (2) HNO_3 (3) = COLD (4) = NaOH (5) = H_2SO_4 (6) = $Na_2S_2O_3$ (7) =

RELINQUISHED BY (SIGN)	PRINT NAME / COMPANY	DATE / TIME	RECEIVED BY (SIGN)	PRINT NAME / COMPANY
Lara Pucik Christensen	Lara Pucik Christensen / WAI	2.6.06 15:45		

REC'D AT LAB BY: [signature] DATE / TIME: 2-6-6 1545 CONDITIONS / COMMENTS: 7°

SHIPPED BY: ☐ FED X ☐ UPS ☐ OTHER ____ AIR BILL #

LAB

CALIFORNIA LABORATORY SERVICES

02/15/06 12:54

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPB0184
COC #: 69199

CAM 17 Metals

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Composite 4A-C (CPB0184-04) Water	**Sampled: 02/06/06 00:00**		**Received: 02/06/06 15:45**						
Arsenic	ND	5.0	µg/L	1	CP00903	02/07/06	02/08/06	EPA 200.8	
Lead	ND	50	"	10	"	"	"	"	QRL-6
Selenium	ND	5.0	"	1	"	"	"	"	
Thallium	ND	100	"	10	"	"	"	"	QRL-6
Antimony	ND	50	"	1	CP00905	02/07/06	02/08/06	EPA 200.7	
Barium	**1500**	20	"	"	"	"	"	"	
Beryllium	ND	5.0	"	"	"	"	"	"	
Cadmium	ND	10	"	"	"	"	"	"	
Cobalt	ND	20	"	"	"	"	"	"	
Chromium	**47**	20	"	"	"	"	"	"	
Copper	ND	20	"	"	"	"	"	"	
Molybdenum	**40**	20	"	"	"	"	"	"	
Nickel	ND	20	"	"	"	"	"	"	
Silver	ND	10	"	"	"	"	"	"	
Vanadium	ND	20	"	"	"	"	"	"	
Zinc	ND	20	"	"	"	"	"	"	
Mercury	ND	0.20	"	"	CP00961	02/08/06	02/09/06	EPA 245.1	

CALIFORNIA LABORATORY SERVICES

02/15/06 12:54

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPB0184
COC #: 69199

Conventional Chemistry Parameters by APHA/EPA Methods

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Composite 4A-C (CPB0184-04) Water	**Sampled: 02/06/06 00:00**		**Received: 02/06/06 15:45**						
Total Alkalinity	**740**	5.0	mg/L	1	CP00909	02/07/06	02/07/06	EPA 310.1	
Bicarbonate as CaCO3	ND	5.0	"	"	"	"	"	"	
Carbonate as CaCO3	**100**	5.0	"	"	"	"	"	"	
Hydroxide as CaCO3	**640**	5.0	"	"	"	"	"	"	
Specific Conductance (EC)	**3700**	1.0	µmhos/cm	"	CP00923	02/08/06	02/08/06	EPA 120.1	
Hexavalent Chromium	**39**	1.0	µg/L	"	CP00875	02/07/06	02/07/06	EPA 7199	
Hexavalent Chromium, Dissolved	**38**	1.0	"	"	"	"	"	"	
pH	**12.01**		pH Units	"	CP00887	"	02/07/06	EPA 150.1	
Total Dissolved Solids	**1200**	10	mg/L	"	CP00945	02/08/06	02/08/06	EPA 160.1	

CALIFORNIA LABORATORY SERVICES

 02/15/06 12:54

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPB0184
COC #: 69199

Metals (Dissolved) by EPA 200 Series Methods

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Composite 4A-C (CPB0184-04) Water	**Sampled: 02/06/06 00:00**		**Received: 02/06/06 15:45**						
Aluminum	ND	50	µg/L	1	CP00905	02/07/06	02/08/06	EPA 200.7	
Barium	**1400**	20	"	"	"	"	"	"	
Calcium	**380000**	1000	"	"	"	"	"	"	
Chromium	**45**	10	"	"	"	"	"	"	
Iron	ND	100	"	"	"	"	"	"	
Magnesium	ND	1000	"	"	"	"	"	"	
Molybdenum	**39**	20	"	"	"	"	"	"	
Potassium	**30000**	1000	"	"	"	"	"	"	
Sodium	**92000**	1000	"	"	"	"	"	"	
Vanadium	ND	20	"	"	"	"	"	"	
Boron	**270**	50	"	"	"	"	"	"	

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPB0184
COC #: 69199

CAM 17 Metals - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00903 - EPA 3020A										
Blank (CP00903-BLK1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Arsenic	ND	5.0	µg/L							
Lead	ND	5.0	"							
Selenium	ND	5.0	"							
Thallium	ND	10	"							
LCS (CP00903-BS1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Arsenic	91.8	5.0	µg/L	100		91.8	80-120			
Lead	92.8	5.0	"	100		92.8	80-120			
Selenium	91.8	5.0	"	100		91.8	80-120			
Thallium	96.6	10	"	100		96.6	80-120			
LCS Dup (CP00903-BSD1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Arsenic	96.3	5.0	µg/L	100		96.3	80-120	4.78	20	
Lead	97.1	5.0	"	100		97.1	80-120	4.53	20	
Selenium	96.6	5.0	"	100		96.6	80-120	5.10	20	
Thallium	101	10	"	100		101	80-120	4.45	20	
Matrix Spike (CP00903-MS1)	**Source: CPB0164-01**			Prepared: 02/07/06 Analyzed: 02/08/06						
Arsenic	103	5.0	µg/L	100	ND	103	75-125			
Lead	94.6	5.0	"	100	0.79	93.8	75-125			
Selenium	91.2	5.0	"	100	1.3	89.9	75-125			
Thallium	100	10	"	100	0.18	99.8	75-125			
Matrix Spike Dup (CP00903-MSD1)	**Source: CPB0164-01**			Prepared: 02/07/06 Analyzed: 02/08/06						
Arsenic	98.1	5.0	µg/L	100	ND	98.1	75-125	4.87	25	
Lead	90.4	5.0	"	100	0.79	89.6	75-125	4.54	25	
Selenium	86.9	5.0	"	100	1.3	85.6	75-125	4.83	25	
Thallium	96.6	10	"	100	0.18	96.4	75-125	3.46	25	

Walker & Associates, Inc.	Project: CMAC	
2618 J Street, Suite 1	Project Number: [none]	**CLS Work Order #: CPB0184**
Sacramento, CA 95816	Project Manager: Lara Christensen	COC #: 69199

CAM 17 Metals - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00905 - EPA 3010A										
Blank (CP00905-BLK1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Antimony	ND	50	µg/L							
Barium	ND	20	"							
Beryllium	ND	5.0	"							
Cadmium	ND	10	"							
Cobalt	ND	20	"							
Chromium	ND	20	"							
Copper	ND	20	"							
Molybdenum	ND	20	"							
Nickel	ND	20	"							
Silver	ND	10	"							
Vanadium	ND	20	"							
Zinc	ND	20	"							
LCS (CP00905-BS1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Antimony	550	50	µg/L	500		110	80-120			
Barium	2070	20	"	2000		104	80-120			
Beryllium	51.5	5.0	"	50.0		103	80-120			
Cadmium	56.5	10	"	50.0		113	80-120			
Cobalt	526	20	"	500		105	80-120			
Chromium	210	20	"	200		105	80-120			
Copper	260	20	"	250		104	80-120			
Molybdenum	527	20	"	500		105	80-120			
Nickel	517	20	"	500		103	80-120			
Silver	48.0	10	"	50.0		96.0	80-120			
Vanadium	521	20	"	500		104	80-120			
Zinc	510	20	"	500		102	80-120			
LCS Dup (CP00905-BSD1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Antimony	530	50	µg/L	500		106	80-120	3.70	20	
Barium	2040	20	"	2000		102	80-120	1.46	20	
Beryllium	50.6	5.0	"	50.0		101	80-120	1.76	20	
Cadmium	57.8	10	"	50.0		116	80-120	2.27	20	

CALIFORNIA LABORATORY SERVICES

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPB0184
COC #: 69199

CAM 17 Metals - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00905 - EPA 3010A										
LCS Dup (CP00905-BSD1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Cobalt	515	20	µg/L	500		103	80-120	2.11	20	
Chromium	202	20	"	200		101	80-120	3.88	20	
Copper	256	20	"	250		102	80-120	1.55	20	
Molybdenum	520	20	"	500		104	80-120	1.34	20	
Nickel	512	20	"	500		102	80-120	0.972	20	
Silver	48.1	10	"	50.0		96.2	80-120	0.208	20	
Vanadium	513	20	"	500		103	80-120	1.55	20	
Zinc	501	20	"	500		100	80-120	1.78	20	
Matrix Spike (CP00905-MS1)		**Source: CPB0164-01**		Prepared: 02/07/06 Analyzed: 02/08/06						
Antimony	588	50	µg/L	500	63	105	75-125			
Barium	4010	20	"	2000	2000	100	75-125			
Beryllium	51.7	5.0	"	50.0	ND	103	75-125			
Cadmium	57.2	10	"	50.0	ND	114	75-125			
Cobalt	524	20	"	500	ND	105	75-125			
Chromium	237	20	"	200	33	102	75-125			
Copper	309	20	"	250	53	102	75-125			
Molybdenum	526	20	"	500	ND	105	75-125			
Nickel	522	20	"	500	ND	104	75-125			
Silver	48.6	10	"	50.0	ND	97.2	75-125			
Vanadium	523	20	"	500	ND	105	75-125			
Zinc	744	20	"	500	250	98.8	75-125			
Matrix Spike Dup (CP00905-MSD1)		**Source: CPB0164-01**		Prepared: 02/07/06 Analyzed: 02/08/06						
Antimony	584	50	µg/L	500	63	104	75-125	0.683	25	
Barium	4120	20	"	2000	2000	106	75-125	2.71	25	
Beryllium	52.2	5.0	"	50.0	ND	104	75-125	0.962	25	
Cadmium	60.6	10	"	50.0	ND	121	75-125	5.77	25	
Cobalt	529	20	"	500	ND	106	75-125	0.950	25	
Chromium	241	20	"	200	33	104	75-125	1.67	25	
Copper	313	20	"	250	53	104	75-125	1.29	25	
Molybdenum	534	20	"	500	ND	107	75-125	1.51	25	

CALIFORNIA LABORATORY SERVICES

02/15/06 12:54

Walker & Associates, Inc.	Project: CMAC	
2618 J Street, Suite 1	Project Number: [none]	**CLS Work Order #: CPB0184**
Sacramento, CA 95816	Project Manager: Lara Christensen	COC #: 69199

CAM 17 Metals - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00905 - EPA 3010A										
Matrix Spike Dup (CP00905-MSD1)	**Source: CPB0164-01**			Prepared: 02/07/06	Analyzed: 02/08/06					
Nickel	521	20	µg/L	500	ND	104	75-125	0.192	25	
Silver	48.6	10	"	50.0	ND	97.2	75-125	0.00	25	
Vanadium	529	20	"	500	ND	106	75-125	1.14	25	
Zinc	762	20	"	500	250	102	75-125	2.39	25	
Batch CP00961 - EPA 7470A										
Blank (CP00961-BLK1)				Prepared: 02/08/06	Analyzed: 02/09/06					
Mercury	ND	0.20	µg/L							
LCS (CP00961-BS1)				Prepared: 02/08/06	Analyzed: 02/09/06					
Mercury	5.85	0.20	µg/L	5.00		117	75-125			
LCS Dup (CP00961-BSD1)				Prepared: 02/08/06	Analyzed: 02/09/06					
Mercury	5.62	0.20	µg/L	5.00		112	75-125	4.01	25	
Matrix Spike (CP00961-MS1)	**Source: CPB0164-01**			Prepared: 02/08/06	Analyzed: 02/09/06					
Mercury	5.70	0.20	µg/L	5.00	ND	114	75-125			
Matrix Spike Dup (CP00961-MSD1)	**Source: CPB0164-01**			Prepared: 02/08/06	Analyzed: 02/09/06					
Mercury	5.66	0.20	µg/L	5.00	ND	113	75-125	0.704	25	

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02/15/06 12:54

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPB0184
COC #: 69199

Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00875 - General Prep										
Blank (CP00875-BLK1)				Prepared & Analyzed: 02/07/06						
Hexavalent Chromium	ND	1.0	µg/L							
Hexavalent Chromium, Dissolved	ND	1.0	"							
LCS (CP00875-BS1)				Prepared & Analyzed: 02/07/06						
Hexavalent Chromium	5.48	1.0	µg/L	5.00		110	80-120			
Hexavalent Chromium, Dissolved	5.48	1.0	"	5.00		110	80-120			
LCS Dup (CP00875-BSD1)				Prepared & Analyzed: 02/07/06						
Hexavalent Chromium	5.29	1.0	µg/L	5.00		106	80-120	3.53	20	
Hexavalent Chromium, Dissolved	5.29	1.0	"	5.00		106	80-120	3.53	20	
Matrix Spike (CP00875-MS1)	**Source: CPB0184-04**			Prepared & Analyzed: 02/07/06						
Hexavalent Chromium	47.0	1.0	µg/L	5.00	39	160	75-125			QM-5
Hexavalent Chromium, Dissolved	47.0	1.0	"	5.00	38	180	75-125			QM-5
Matrix Spike Dup (CP00875-MSD1)	**Source: CPB0184-04**			Prepared & Analyzed: 02/07/06						
Hexavalent Chromium	48.2	1.0	µg/L	5.00	39	184	75-125	2.52	25	QM-5
Hexavalent Chromium, Dissolved	48.2	1.0	"	5.00	38	204	75-125	2.52	25	QM-5
Batch CP00909 - General Preparation										
Blank (CP00909-BLK1)				Prepared & Analyzed: 02/07/06						
Total Alkalinity	ND	5.0	mg/L							
Bicarbonate as CaCO3	ND	5.0	"							
Carbonate as CaCO3	ND	5.0	"							
Hydroxide as CaCO3	ND	5.0	"							

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02/15/06 12:54

Walker & Associates, Inc. 2618 J Street, Suite 1 Sacramento, CA 95816	Project: CMAC Project Number: [none] Project Manager: Lara Christensen	**CLS Work Order #: CPB0184** COC #: 69199

Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00923 - General Preparation										
Blank (CP00923-BLK1)				Prepared & Analyzed: 02/08/06						
Specific Conductance (EC)	ND	1.0	µmhos/cm							
Batch CP00945 - General Preparation										
Blank (CP00945-BLK1)				Prepared & Analyzed: 02/08/06						
Total Dissolved Solids	ND	10	mg/L							

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02/15/06 12:54

Walker & Associates, Inc. 2618 J Street, Suite 1 Sacramento, CA 95816	Project: CMAC Project Number: [none] Project Manager: Lara Christensen	**CLS Work Order #: CPB0184** COC #: 69199

Metals (Dissolved) by EPA 200 Series Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00905 - EPA 3010A										
Blank (CP00905-BLK1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Aluminum	ND	50	µg/L							
Barium	ND	20	"							
Calcium	ND	1000	"							
Chromium	ND	10	"							
Iron	ND	100	"							
Magnesium	ND	1000	"							
Molybdenum	ND	20	"							
Potassium	ND	1000	"							
Sodium	ND	1000	"							
Vanadium	ND	20	"							
Boron	ND	50	"							
LCS (CP00905-BS1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Aluminum	2070	50	µg/L	2000		104	80-120			
Barium	2070	20	"	2000		104	80-120			
Calcium	10300	1000	"	10000		103	80-120			
Chromium	210	10	"	200		105	80-120			
Iron	1020	100	"	1000		102	80-120			
Magnesium	10300	1000	"	10000		103	80-120			
Molybdenum	527	20	"	500		105	80-120			
Potassium	10100	1000	"	10000		101	80-120			
Sodium	10400	1000	"	10000		104	80-120			
Vanadium	521	20	"	500		104	80-120			
Boron	2560	50	"	2500		102	80-120			
LCS Dup (CP00905-BSD1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Aluminum	2040	50	µg/L	2000		102	80-120	1.46	20	
Barium	2040	20	"	2000		102	80-120	1.46	20	
Calcium	10200	1000	"	10000		102	80-120	0.976	20	
Chromium	202	10	"	200		101	80-120	3.88	20	
Iron	1010	100	"	1000		101	80-120	0.985	20	
Magnesium	10100	1000	"	10000		101	80-120	1.96	20	

CALIFORNIA LABORATORY SERVICES

Walker & Associates, Inc.
2618 J Street, Suite 1
Sacramento, CA 95816

Project: CMAC
Project Number: [none]
Project Manager: Lara Christensen

CLS Work Order #: CPB0184
COC #: 69199

Metals (Dissolved) by EPA 200 Series Methods - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch CP00905 - EPA 3010A										
LCS Dup (CP00905-BSD1)				Prepared: 02/07/06 Analyzed: 02/08/06						
Molybdenum	520	20	µg/L	500		104	80-120	1.34	20	
Potassium	9900	1000	"	10000		99.0	80-120	2.00	20	
Sodium	10200	1000	"	10000		102	80-120	1.94	20	
Vanadium	513	20	"	500		103	80-120	1.55	20	
Boron	2520	50	"	2500		101	80-120	1.57	20	
Matrix Spike (CP00905-MS1)	**Source: CPB0164-01**			Prepared: 02/07/06 Analyzed: 02/08/06						
Aluminum	2360	50	µg/L	2000	300	103	75-125			
Barium	4010	20	"	2000	2000	100	75-125			
Calcium	12900	1000	"	10000	2800	101	75-125			
Chromium	237	10	"	200	33	102	75-125			
Iron	1120	100	"	1000	98	102	75-125			
Magnesium	16300	1000	"	10000	6100	102	75-125			
Molybdenum	526	20	"	500	ND	105	75-125			
Potassium	57200	1000	"	10000	49000	82.0	75-125			
Sodium	15700	1000	"	10000	5400	103	75-125			
Vanadium	523	20	"	500	ND	105	75-125			
Boron	2630	50	"	2500	94	101	75-125			
Matrix Spike Dup (CP00905-MSD1)	**Source: CPB0164-01**			Prepared: 02/07/06 Analyzed: 02/08/06						
Aluminum	2390	50	µg/L	2000	300	104	75-125	1.26	25	
Barium	4120	20	"	2000	2000	106	75-125	2.71	25	
Calcium	13200	1000	"	10000	2800	104	75-125	2.30	25	
Chromium	241	10	"	200	33	104	75-125	1.67	25	
Iron	1130	100	"	1000	98	103	75-125	0.889	25	
Magnesium	16600	1000	"	10000	6100	105	75-125	1.82	25	
Molybdenum	534	20	"	500	ND	107	75-125	1.51	25	
Potassium	58900	1000	"	10000	49000	99.0	75-125	2.93	25	
Sodium	16000	1000	"	10000	5400	106	75-125	1.89	25	
Vanadium	529	20	"	500	ND	106	75-125	1.14	25	
Boron	2670	50	"	2500	94	103	75-125	1.51	25	

Walker & Associates, Inc.	Project: CMAC	
2618 J Street, Suite 1	Project Number: [none]	**CLS Work Order #: CPB0184**
Sacramento, CA 95816	Project Manager: Lara Christensen	COC #: 69199

Notes and Definitions

QRL-6	The reporting limit was raised for this analyte because the sample was originally analyzed with no dilution but the internal standard was outside the method criteria. The sample was re-analyzed with a dilution and the internal standard was in control.
QM-5	The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.
DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference