STORM WATER SOLUTIONS

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ABSTRACT

Municipal solid waste facility owners and operators in California are facing a big challenge with the proposed Industrial Storm Water Discharge Permit program revisions. Stricter water quality standards will require costly improvements to the current storm water management systems. Proactive owners/operators have taken measures to limit these effects by making improvements now instead of after the standards go into effect. The authors have designed and constructed improvements for several proactive owners/operators. System improvements have included in-line oil/water separators, large scale sand filtrations basins, high-flow filtration and carbon polishing, and zero discharge modifications. Our paper focuses on two such systems – one involving large-scale sand filtration and the second is zero discharge.

The large scale sand filtration system was designed for a transfer facility for a storm water capacity in the range of 1 to 5 cubic feet per second (cfs). This system is capable of primary treatment of this volume of storm water to reduce turbidity, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), metals, and electrical conductivity. Construction details and photographs of the filter are included in this paper.

Zero storm water discharge is a great objective, but it is not always feasible to design and construct. The facility in our paper is a transfer station where runoff from material handling is routed through a newly constructed bio-swale with holding and infiltration capability. The result is zero discharge from the facility and avoidance with the stricter discharge requirements of the proposed Industrial Discharge Standards. Details and photographs of the system will be presented.

INTRODUCTION AND APPLICABILITY

Information presented in this conference paper was obtained from various sites within California that the authors have provided designs to improve industrial storm water quality prior to discharge. Specifically, the designs herein focused on eliminating or reducing the number of outfalls; thus, minimizing costly monitoring and reporting requirements to achieve an effluent that meets or exceeds discharge requirements. The treatment and outfall reduction designs are also cost-effective solutions that may be implemented in a timely manner and offer a few approaches feasible for use at some industrial sites. In California, current storm water compliance requirements are set forth in Industrial Storm Water General Permit Order 97-03-DWQ.

The authors have successfully applied these storm water treatment designs to Materials Recovery Facilities (MRFs) and Transfer Stations within the state of California and believe that most principals would apply throughout the country or the world for that matter.

GENERAL ONSITE TREATMENT OPTIONS

In general, the best options for storm water (SW) handling for any site is to keep it onsite, if possible, so as not to create any discharge to receiving waters. This is not always possible, but if adequate space is available, the approach to handling the site's SW may be as simple as implementing an onsite treatment or non-treatment option. Each of these options require an engineered design based either on theory, pilot-test results, engineering studies, and/or proven technologies that have successfully been implemented and shown to be effective. A few of the most common options are as follows.

Treatment options include, but are not limited to, settling tanks or ponds, constructed wetlands, sand filtration, and membrane biological reactor systems, reverse osmosis, etc., or perhaps some combination thereof. In this paper we present designs on a Large-Scale Sand Filter (LSSF) as a treatment option and an Infiltration Basin as a non-treatment option alternative. The LSSF may be used as a stand-alone treatment mechanism or in combination with primary clarifiers, oil/water separators (OWS), or other devices to provide a water that is suitable to meet discharge requirements.

It should be noted that the options we present in this conference paper are site-specific remedies based upon many design considerations and may not be applicable to address discharge concerns at every site with SW related issues. A few things to consider during the design selection process of a storm water treatment device or train, including general informational needs to select an appropriate corrective measure for a given site are discussed below.

DESIGN CONSIDERATIONS/INFORMATIONAL NEEDS

Lab results (over the last few years, if possible) for the facility's storm water runoff that are representative of current and anticipated operations. These results will be used along with the regulatory benchmarks [e.g., numerical action limits (NALs), WQLs, etc.] for the compounds, metal ions, and geo-chemicals of concern to determine their potential reduction and used in part to select an appropriate remedial action for the site. The next information you need is HydroCAD® or other SW runoff modeling results, current topography, property boundaries, etc., to determine design parameters and site constraints. Next, and of equal importance, are your client's expectations, available monies, deliverable deadlines and most of all regulatory compliance deadlines. These are a few considerations and informational needs you will have to evaluate to provide a cost-effective solution that adequately addresses site concerns.

Considerations for the designs we present were primarily based on the volume of expected SW effluent which was quite large for both cases. For our onsite treatment design, we selected a LSSF after finding that most turn-key industrial treatment units held a fairly large price tag and require frequent media replacement and ongoing operation and maintenance (O&M) costs which can quickly add up. We also found that O&M for these types of systems were generally not user-friendly and required trained technicians or site personnel whom were well-versed in operation of such systems which are hard to come by if I may be so bold. Lower cost turn-key units were also generally able to handle about 200 gallons per minute (gpm), which equates to approximately a half cubic feet per second (cfs) (a relatively low flow rate for facilities that typically extend over several acres and reside in wet weather climates). Our sites were on the order of 1 to 5 cfs; therefore, other solutions were necessary to process those flow rates. More importantly, our designs aimed at providing cost-effective treatment strategies that would provide an effluent that meets or exceeds industrial SW discharge requirements.

California requires that SW treatment processes be determined for a minimum 10-year, 24-hr storm. In our case, the LSSF was designed for 6 cfs. At this flow, even a reasonably priced turn-key treatment unit would require sufficient holding tanks or other, and the combined cost of these additional measures would escalate the cost of such treatment, notwithstanding the necessary space requirements for such treatment trains.

GENERAL PERMITTING REQUIREMENTS

In order to install the types of treatment systems discussed in this paper, a local grading permit will likely be required if more than an acre is disturbed or if a certain number of cubic yards is moved our placed during grading (which is normally the case for large-scale sand filters and infiltration basins). This permit also typically includes environmental review and acceptance by the governing agency prior to the subject site receiving approval to construct the design. One noteworthy aspect of this permit is if the facility has historically had discharge issues and perhaps a Cease and Desist Order (CDO), regulators usually expedite review and acceptance for most corrective efforts so that treatment of SW discharge may begin. They also are quite pleased when a treatment design is aimed at reduction of outfalls and absolutely elated if the design is aimed at zero discharge, the holy grail of minimizing impacts to receiving waters and the environment.

The grading permit will also require a permit-level design (typically, 90% Completion), including drawings that show the locations of erosion control devices and measures [i.e., best management practices (BMPs)] that will need to be implemented during the project work. Please note that even though your project may not require a Notice of Intent (NOI) which requires a storm water pollution Prevention Plan (SWPPP), based upon acreage disturbed, in most cases you will be required to have an erosion control plan written by a Qualified SWPPP Practitioner (QSP) and reviewed and accepted by a Qualified SWPPP Developer (QSD). The QSP or QSD will also have to verify that the control measures have been installed, effective, and remain functional during and after construction prior to being issued a Notice of Termination (NOT), after which point the project is deemed complete.

In addition to the above, once the selected treatment system is constructed and operational, the facility will have to abide by the guidelines and discharge requirements set forth in the given state's General Industrial Storm Water Permit (Permit). Effective July 2015, the Permit will include even stricter requirements that carry big consequences should your site's effluent not meet numerical action limits. These include, but are not limited to, expanded documentation of BMP control measures, comprehensive training to qualify site personnel, and increased frequency of reporting. These requirements increase operational costs throughout the life of site operations that contribute to, or potentially impact storm water. Moreover, if initial sampling results indicate that regulatory discharge requirements have been exceeded, the protocol of the Permit becomes more intensive; therefore, more expensive. Please note that permitting requirements vary from district to district and from state to state but be assured that the requirements in your state will not lessen by any means.

OVERVIEW OF DESIGNS

The first design uses an on old filtration idea which was proven back then and still worth its weight in gold, or sand in this circumstance. It is a sand filter, but not just an ordinarily sand filter. It is a large-scale sand filter system that that has the ability to process high flows, utilizes gravity, does not require additional bells and whistles, only minimal O&M which clients can always appreciate.

No, not all facilities have the convenience of placing a filtration system at a lower elevation than their site, but even if you have to pump site effluent into your treatment system, your lower capital cost and minimal O&M requirements will make your breakeven point in a few years, not decades as with most common water treatment facilities that include multiple-tiered processes.

The figure below (FIGURE 1), presented to show the magnitude of the size of the LSSF, is one recent design that included low-cost upgrades to provide primary and secondary treatment and provides tertiary treatment of MRF Stormwater run-off.

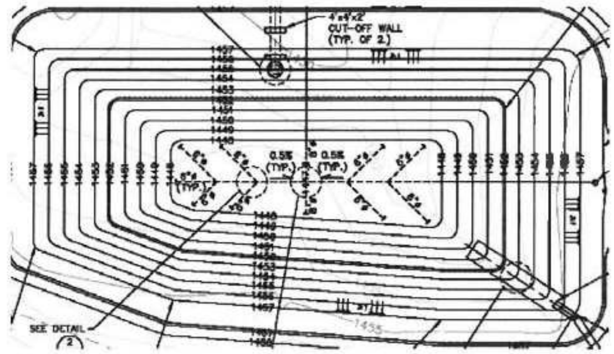

FIGURE 1

This figure shows the plan view of the LSSF (105 feet by 50 feet) which you can see is actually a detention basin with sand filtration capability and has the storage capacity of nearly 200,000 gallons!

SAND FILTER SYSTEM DESIGN & CONSTRUCTION

The design of the sand filter portion of this basin uses a 12-ounce geotextile below a 3-foot layer of #4x#50 filter media (sand), a 16-inch layer of drainage rock layer with perforated 6" diameter SCH 80 PVC, and a layer of 12-ounce geotextile below the rock and pipe to separate the drainage media from the foundation layer of the basin. The sand filter section below (FIGURE 2) shows a general arrangement of materials. The flow through this media should be equal to or slightly greater than the design flow. In our case the flow into the basin was 5.5 cfs and the sand filter portion of the system, including geotextile layers, drainage rock, and pipe perforation density was sized to process a slightly greater flow of approximately 5.8 cfs to avoid back-up and overflow of the basin while providing adequate filtration.

FIGURE 2

The sand filter design is based on Darcy's law:

$$Q = KiA = VA \text{ (since } V = Ki)$$

Where,
Q = WQ design flow (cfs)
K = hydraulic conductivity (fps)
A = surface area perpendicular to the direction of flow (sf)

i = hydraulic gradient (ft/ft) for a constant head and constant media depth, computed as follows:

$$i = (h + l) / l$$

Where, $h = d/2$ = average depth of water above filter (ft),
d = maximum storage depth above filter (ft)
l = thickness of sand media (typically 1.5 ft)

Photos showing the construction of the LSSF underdrain piping and sand media placement over the drain rock and upper geotextile layer are included as FIGURES 3 and 4, respectively.

FIGURE 3

FIGURE 4

A few other site constraints were as followed. Our total area was limited for construction (~0.2 acre, including daylighting of basin) due to adjacent river, property, and sewer easements which bound the basin area. Also, the depth of groundwater was very shallow within the basin area which meant that we had to design a basin that would not only allow adequate filtration of incoming flow while providing enough hydraulic head and 2 feet of freeboard, but stay adequately above the ground water table, thus limiting the total excavation depth.

To control water levels while achieving adequate head, we designed an overflow structure, consisting of 24-inch diameter steel pipe and an elbow and reducer as opposed to using a costly large vertical concrete overflow structure that is typically used for these applications. Also, using a typical parallel arrangement (section of pipe laid horizontally), we would lose approximately the diameter of the overflow pipe (24" head) since it is the top of the pipe invert that is used as the datum to measure freeboard depth. To overcome this obstacle, we designed an overflow assembly with its inlet perpendicular to the basin floor much like the drain in your sink. This configuration saved us 2 feet of liquid head and when sufficient constant head is the prerequisite to have a properly functioning sand filter, this type of overflow pipe configuration can be your best friend. The figure below (FIGURE 5) shows the configuration of the overflow pipe used for our LSSF.

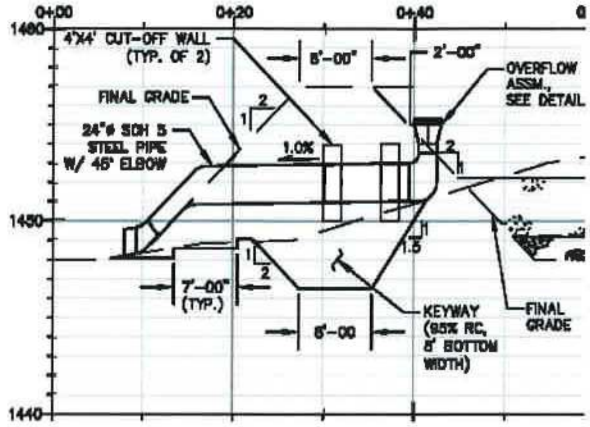

FIGURE 5

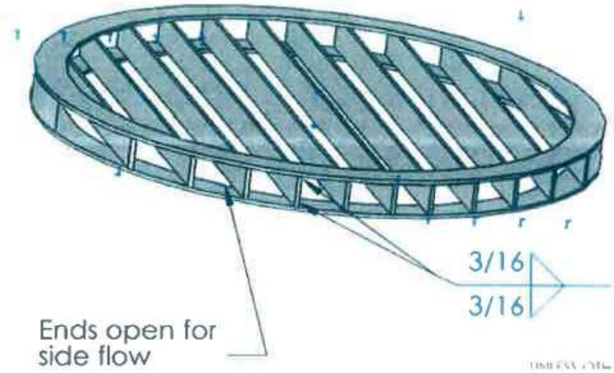

FIGURE 7

A detail and perspective view of the overflow assembly are included below as FIGURES 6 and 7, respectively.

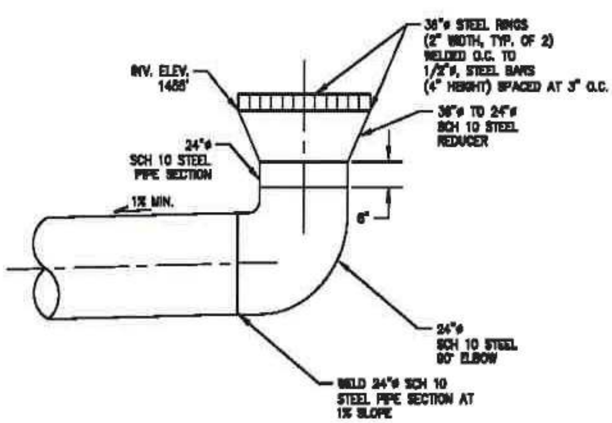

FIGURE 6

This design also included interesting modifications of two (2) other site areas. The first area, where some primary treatment occurs is approximately ¼-mile from the LSSF. This catchment area was modified by use of a precast vault that had the total capacity of 1,200 gallons, of which 800 gallons was used to contain SW runoff and the remainder of the vault was used to catch petroleum spills from truck refueling mishaps. The vault itself was custom fabricated by the vendor (Jensen Precast®) which included openings for an incoming SW swale on one side and a rectangular opening on the adjacent side that functions similar to a curb inlet. The precast vault was also built to provide a separation wall between general SW and fuel spill containment to keep these worlds separated. Other ancillary equipment included an irrigation gate valve to enable the vault to be closed off from the outlet culvert should a large fuel spill occur. This modification also eliminated a site outfall, the primary reason for the design, and directed storm water from this site area via a culvert to the next treatment area. FIGURE 8 presents a detail of the custom precast dual-purpose vault.

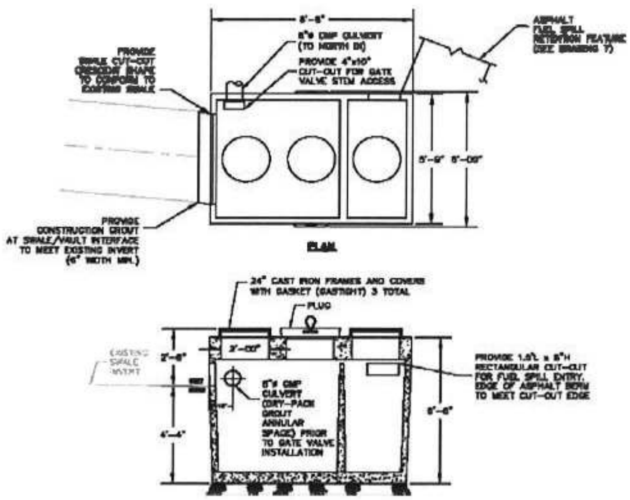

FIGURE 8

The next area requiring modification to site's SW treatment system was to retrofit a precast pre-sedimentation basin (pre-sed basin) unit between the final connection point of all site DIs and an existing oil/water separator (OWS) via use of a restored existing manhole and a new junction manhole. This allowed for additional primary and secondary treatment of site storm water before being routed to the LSSF.

The pre-sed basin was designed to handle 450 gallons per minute (gpm), with a total flow capacity of 600 gpm to handle overflow conditions. This proved to be quite a challenge for the contractor, but after some slight modifications to the design based on field findings and reuse of existing facilities in the area, we found a creative way to retrofit the SW structures and provide additional primary and secondary treatment components without losing the ability to process a storm water discharge of nearly 6 cfs. FIGURE 9 shows the junction retrofit area.

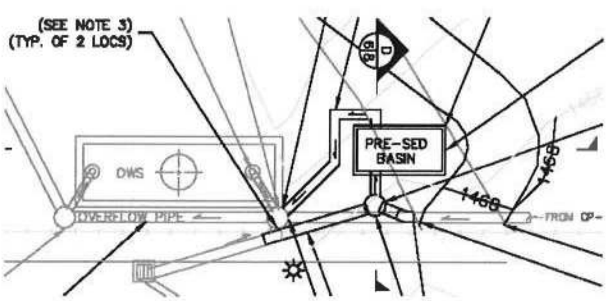

FIGURE 9

This design, including the additional treatment components, reduced BOD and COD to half their original concentrations and removed upwards of 95 percent of TSS, and metals to a fraction of their NALs, and was shown to provide an effluent that met water quality standards. So, if you need to clean up industrial storm water from one of your sites, consider using this type of treatment design as a viable option. As discussed, we had many constraints and a rather large volume of water that required intensive treatment and only needed 1/5 of an acre, 200 cubic yards of sand media, and limited lengths of steel and PVC Pipe to make it happen. Also, O&M of this LSSF was limited to simply scraping and replacing 4 inches or so of sand media and back flushing the underdrain system (via use of a fire hose through a cleanout located at the top of the basin slope) on an annual basis. I would argue that most, if not all, site personnel could perform these duties with low to no training and the treatment system would operate as normal. Compare that with monthly O&M, coagulants, media replacement and occasional equipment breakdowns using a mechanical process.

Another option for onsite handling of SW is likely not as fascinating as the LSSF presented above, but also uses an age-old idea which will make your storm water discharge disappear right before your very eyes-not by magic but by using percolation. If you can manage to reduce your discharge points or achieve zero discharge, then regulators will likely leave your site alone for all intents and purposes. The design of one successfully implemented infiltration basin and affiliated design considerations are presented below.

INFILTRATION BASIN DESIGN

Design considerations and informational needs for this onsite strategy are similar to the aforementioned treatment system; although, an infiltration study was required to determine if this site was amiable to this SW disposal method. The study yielded favorable results and required various model inputs to confirm that the model adequately represented actual site infiltration capability.

Permitting for this onsite storm water handling option was similar to the previous design but in this case the grading under the permit included primarily excavation since the infiltration basin was entirely below grade. Again, permitting agency charges were based on acreage disturbed, volume of soil removed, and required associated environmental review prior to permit approval.

This design also required a fairly in-depth storm water runoff assessment because many existing facilities were to be reused to the extent possible. We; therefore, modeled three (3) distinct site areas using HydroCAD® and the contributing areas were divided into individual catchment areas with runoff directed to any given area as needed by using a series of asphalt berms and existing site grades to route runoff to existing site drainage facilities [i.e., drop inlets (DIs), asphalt swales, asphalt berms, etc.]. This allowed us to increase or decrease any contributing area to provide a complete storm water management design that would effectively handle anticipated site storm water within the individual site areas without overburdening any one area.

This design incorporated the use of existing site DIs, and included connection to existing culvert sections and modifications to route storm water to the infiltration basin. New DIs and culverts were also designed for a smaller infiltration swale located in another site area. The infiltration basin was also equipped with an overflow drainage swale and weir prior to reaching the outfall should the design storm be exceeded. The plan view of this basin is shown in FIGURE 10.

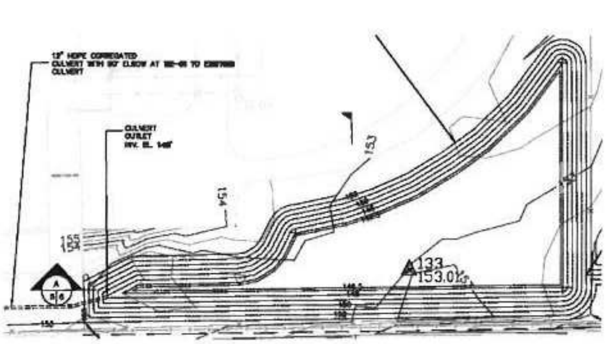

FIGURE 10

The overflow swale, weir, and connection to the infiltration basin are shown on FIGURE 11.

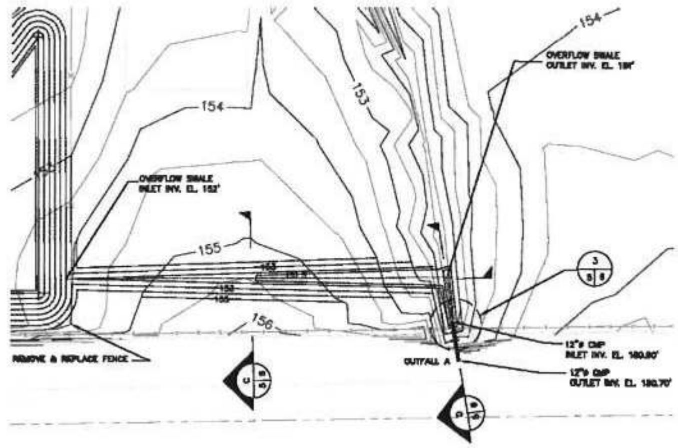

FIGURE 11

The weir for the infiltration basin was designed to provide relief under 2 scenarios. The first being that the weir was connected to an existing swale used for the site's landscaped area so it needed to provide relief during summer irrigation activities so as not to impede natural drainage low flow conditions. Given that, we designed the weir to have the ability to provide relief by use of a culvert set at the existing stream invert. The second scenario is that we aimed to increase the capacity of the connection swale, prior to the weir, thus providing some retention prior to the water elevation reaching the top of the weir prior to overflow. The design; therefore, included a 12-inch diameter pipe plug that is used when inclement weather is expected and removed during the dry season to allow for relief of general irrigation water.

The weir was also designed as a parabolic broad-crested weir to allow for controlled outlet flow and minimize erosion to the unprotected upper portion of and prior to discharge to the adjacent canal. Using this weir type, we were also able to achieve a higher invert and wider discharge width as compared with a typical v-notch or other weir configuration. The outfall was also provided with erosion protection by means of a grouted, rock-lined outfall swale that covered the low-water discharge pipe. This pipe was also designed at an elevation above the high-water mark of the adjacent canal to ensure that only discharge to the canal would be possible and not vice-versa. A plan view and section of this design feature is shown on FIGURES 12 and 13, respectively. A photo of the swale side of the constructed weir is presented as FIGURE 14.

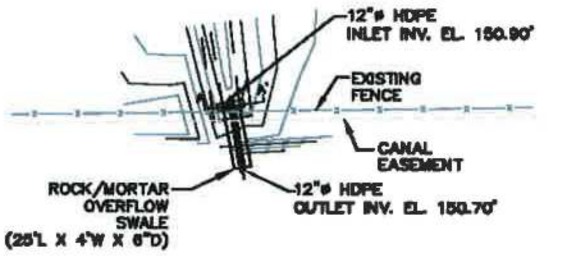

FIGURE 12

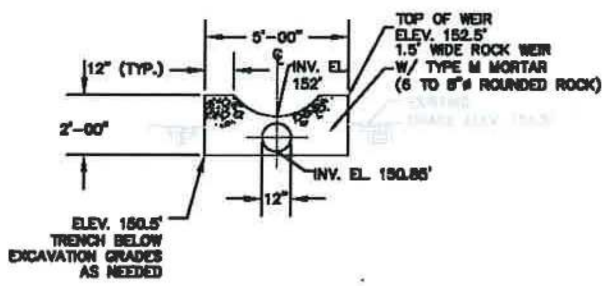

FIGURE 13

FIGURE 14

A few design aspects that may be of interest include the overflow connection swale invert set at a datum where the basin's inlet culvert (Shown on FIGURE 10) would run partially full; thus, creating additional head over the basin, and increasing its capacity prior to discharging to the overflow weir. This design addition has also proven to be quite helpful in reducing runoff prior to being directed to the weir. The design of the overflow connection swale also provided additional capacity prior to discharging over the weir.

To determine the infiltration capability for the basin, we calculated the possible infiltration rate as presented in our basis of design for storm water improvements at the site. The surface area for percolation was found to be approximately 13,150 square feet (sf) using AutoCAD® take-offs. Soil permeability was estimated from literature sources based on local soil type. The average coefficient of permeability (using both vertical and horizontal constants) was calculated to be 1.6×10^{-4} centimeters per second (cm/s). Using this value, we found that for this percolation surface area and an average of 2.75 feet of liquid head, the total percolation for the infiltration basin was 5.8 cubic feet per second (cfs). Comparing this percolation rate to the estimated 2 year, 1 hour storm (5.5 cfs) used for the design (due to limited available site area), the infiltration basin will not discharge into the overflow swale connected to the weir from this 2-year storm event.

COST

Approximate capital costs for construction of both types of systems and their components are included in TABLE 1 and 2 for the LSSF and Infiltration Basin, respectively.

TABLE 1

ITEM	INSTALL COST	MAT. COST	TOTAL COST	DESCRIPT.
1	25,000	5,000	30,000	Precast Oil Spill/Water Vault, Valve. Culvert, DIs
2	20,000	25,000	45,000	Pre-Sed Basin, DIs, Junction MHs, Connection Culverts
3	50,000	40,000	90,000	LSSF components, Inlet & Outlet structures
4	40,000	NA	40,000	Design, Modeling, Permits
OTD* COST			**205,000**	Out-the-door Cost

Note:
*Above cost does not include surveying, construction management, construction quality assurance or operation and maintenance expenses.

TABLE 2

ITEM	INSTALL COST	MAT. COST	TOTAL COST	DESCRIPT.
1	10,000	5,000	15,000	Direction berms, roll curbs, DI
2	2,000	1,000	3,000	DI Sand Filter
3	10,000	NA	10,000	Northern swale
4	40,000	10,000	50,000	Infiltration Basin, connection culverts, Overflow Swale, Weir
5	25,000	NA	25,000	Design, Modeling, Permits
OTD* COST			**103,000**	Out-the-door Cost

Note:
*Above cost does not include surveying, construction management, construction quality assurance or operation and maintenance expenses.

A quick examination of the cost tables above basically shows that the infiltration basin option is roughly half the capital cost of the LSSF for our subject projects that were approximately the same size. The LSSF treatment option was also found to be approximately one third of the cost for a large scale turn-key system that could process the given flow.

CONCLUSIONS

These simple, cost effective designs have been successful at a number of sites in California that have been up against the gun to reduce, eliminate, or improve effluent from their facilities or suffer the consequences of increased SW reporting, sampling, and documenting requirements for as long as they operate. The advantages are in the relatively low construction capital cost, reasonable design costs, quick implementation time, and the success they have to adequately address a site's environmental concerns.

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