

Detention Basins for Water Quality Improvement at a High Mountain Maintenance Station

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An evaluation of a detention basin system at a snow removal maintenance station is documented. In response to concerns by the US Forest Service, the basins were built as a mitigation measure to clarify storm runoff and snowmelt from the maintenance station before it entered Benwood Creek. The creek is a tributary of the headwaters of the South Fork of the American River. A portion of the creek was realigned. The three-basin system, completed in September 1981, is above elevation 7000 feet at the Echo Summit Maintenance Station in California. Sediment and dissolved materials in storm runoff and snowmelt from the maintenance yard were reduced. The capacity of the basins was approximately 10,000 cubic feet as measured in 1982. The basin riser outlets were fitted with grease rings, which retain most oil, grease, and floatables. Snowmelt was sampled and tested in spring 1982. Samples were tested for turbidity, chloride, specific conductance, and oil and grease. Storm runoff in fall 1982, was sampled and tested for turbidity, nonfilterable residue, specific conductance, filterable residue, and chloride. Sediment accumulation in the basins was measured, and a biological assessment of the construction impacts on Benwood Creek was made.

This paper documents an evaluation of a detention basin system for water quality improvement at a snow removal maintenance station. The station is a satellite facility that is used for stockpiling sand, cinders, and deicing salts to keep US 50 open to traffic during the winter. It is located at Echo Summit above elevation 7000 feet in the El Dorado National Forest, Sierra Nevada mountains of California. See figure 1.

Caltrans uses the land under the conditions of a permit issued by the US Forest Service. The Forest Service was concerned that runoff from the maintenance yard was adversely affecting the stream habitat in Benwood Creek, a tributary of the headwaters of the South Fork of the American River. Their measurements showed elevated values of turbidity and specific conductance in the creek. In response to this concern, Caltrans District 3 designed a channel realignment of East Benwood Creek and a detention basin system. The objective was to reduce turbidity and high concentrations of sediment and dissolved materials in the creek due to uncontrolled storm runoff and snowmelt.

Detention basins temporarily hold storm runoff or snowmelt and provide time for the water to clarify before returning to surface or ground water systems. The design criterion for locating the basins was to use existing areas without interfering

with established operations. They were built by contract between the maintenance activity areas and nearby receiving waters.

The Transportation Laboratory (TransLab) of Caltrans evaluated the detention basins in 1982, roughly one year after they were built. There were three phases of evaluation: sampling runoff, measuring and identifying the accumulated sediment, and making a biological assessment of Benwood Creek. The objective of sampling runoff was to compare concentrations of water quality parameters during snowmelt in spring and storms in fall, both upstream and downstream of the basins. Water samples were also collected in the basins. Besides sampling runoff, flow rate and precipitation were also observed and recorded. The sediment measurements were used to estimate basin rates-of-filling and to propose a cleanout schedule. The biological assessment was done to determine the biological potential of the creek and to estimate the effect of constructing the detention basins and channel realignment.

A prelude to any water quality study includes knowledge of the site hydrology and hydraulics. Field trips were made well in advance of the runoff events to design a sampling plan. Using automatic samplers was considered but was not done due to field conditions. A manual sampling plan was adopted and modified as required during runoff events. Enough sampling was done to demonstrate the mitigation effect of the basins. A mass balance was attempted but was not possible because there were no continuous flow records for all drainage areas. Conclusions and findings were based on graphical analyses and recorded observations. Sediment measurements and the biological assessments were done at times other than runoff sampling.

HYDROLOGY—SITE DESCRIPTION

The average annual precipitation measured as rain at Echo Summit is approximately 40 inches. Temperature extremes can range from 2 degrees Fahrenheit in the winter to 80 degrees Fahrenheit in the summer (1). Since the elevation at the maintenance station is above 7000 feet, most of the precipitation is in the form of snow and normally occurs from October through April. Most of the surface runoff is from the spring snowmelt in May and June.

The drainage areas at the maintenance station and nearby, the detention basins, and the sampling locations are shown in figure 2. Benwood Creek originates along the westerly side of the crest of the Sierra Nevada mountains and ultimately

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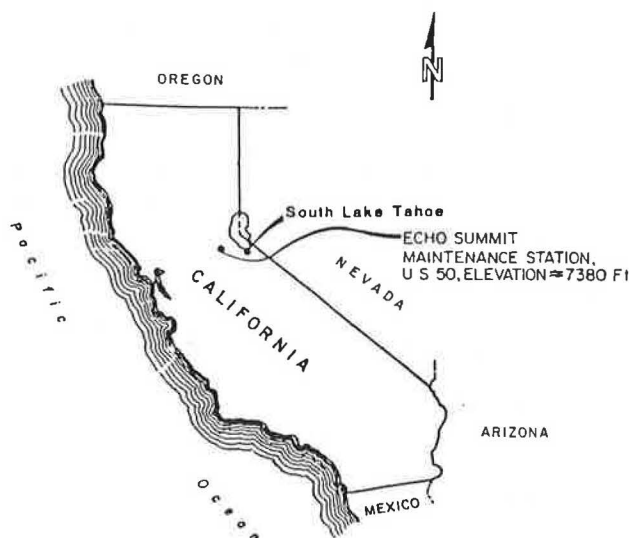


FIGURE 1 Location map.

joins the South Fork of the American River. Observed flows in the creek varied from >6 cubic feet per second (CFS) during snowmelt in spring to <1 CFS in fall toward the end of the dry season. During a dry year the creek may have no flow. The headwaters of Benwood Creek are spring-fed bogs immediately south of US 50 near the maintenance station. Multiple channels merge to form the east and west branches of Benwood Creek before passing under US 50 in culverts. The east and west branches of Benwood Creek receive runoff from areas IV and V. Area IV receives runoff from the headwaters of West Benwood Creek and US 50, while Area V receives runoff from the headwaters of East Benwood Creek and US 50.

The maintenance area, which contributes runoff to the creek, is approximately 5 acres, of which approximately 3 acres are paved with asphalt concrete. Before the detention basins were

built, areas I and III drained to Benwood Creek via overland flow on bare ground. Area II drained to East Benwood Creek, which was connected to Benwood Creek via two 24-inch diameter corrugated steel pipe (CSP) culverts, which are under the maintenance station access road and a Forest Service road.

The detention basins were built to intercept all the runoff from areas I, II, and III. The two basins labeled Upper and Lower are new construction, while the third basin, labeled Old Channel, was the previous alignment of East Benwood Creek. The upper basin intercepts area I (approximately 50 percent), the old channel basin intercepts area II (approximately 45 percent), and the lower basin intercepts area III (approximately 5 percent) of the contributing area. The make-up of the drainage areas is discussed below.

Figure 3 shows a view of the access road from US 50, the salt hopper, sand, and the sand storage shed and a view of the upper and lower basins from the salt hopper. Figures 4 and 5 are close-ups of the upper, lower, and old channel basin and the realigned section of East Benwood Creek. The sides and bottoms of the basins are the local untreated, weathered, granitic soil. Asphalt concrete ramps were constructed in the new basins to allow equipment access for removing sediment. Imported borrow and the on-site excavated material were used to construct the berms that separated the upper and lower basins from each other and from the Forest Service access road and Benwood Creek. A berm was also constructed to separate the old channel basin from the realigned section of East Benwood Creek. It screens the maintenance yard from motorists on US 50. For aesthetic reasons, the basins and berms were contour-graded. Vegetation was left undisturbed where possible. The berms were seeded and containerized native trees and shrubs were planted. Table 1 shows the overall basin dimensions.

If the three basins were initially empty, a rainfall of approximately 0.70 inch would fill them. When the basins were evaluated in 1982, their capacity to detain runoff was approximately 10,000 cubic feet, excluding sediment already accumulated. Runoff that exceeds the capacity of the system

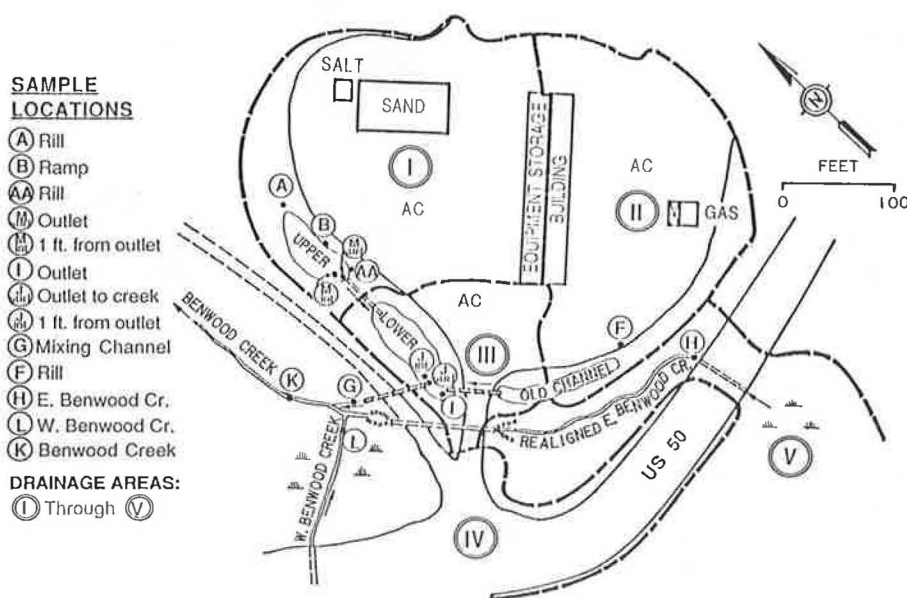


FIGURE 2 Drainage areas and sampling locations.



FIGURE 3 (Top) Entrance to Echo Summit Maintenance Station. (Bottom) Upper and lower detention basins.

is discharged from the lower basin to Benwood Creek. Detained water exits the basins by infiltration into the ground and by evaporation.

HYDRAULIC OPERATION

A schematic diagram of the three detention basins is shown in figure 6. The water surface elevations in the lower and old channel basins are the same, because the basin bottoms are connected by a CSP culvert (40-feet long by 24-inches in diameter) with a 0.1-foot elevation difference. When the basins are full, the upper basin water surface elevation is about 0.5 foot higher than the lower basin. The lower basin water surface elevation is about 2.60 feet higher than Benwood Creek, when the creek is 1.2 feet deep at the confluence with the mixing channel (see below). When the basins overflow excess runoff flows from the upper basin through a CSP outlet riser (2-feet high by 12-inches in diameter) and a CSP culvert (40-feet long by 12-inches in diameter with a 0.2-foot elevation difference) to the lower basin. The outlet riser operates like a circular weir, not a submerged orifice. A grease ring (24-inch diameter perforated CSP) was fitted around the riser. The top of the grease ring is 0.5 foot higher than the top of the outlet riser. Runoff flows through perforations in the grease ring and empties through the outlet riser (not perforated). There are two rows of 3-inch diameter perforations staggered

and spaced approximately 8 inches on-center both horizontally and vertically. When the lower basin overflows, water passes through a CSP outlet riser (3.4 feet high by 24-inches in diameter) into a CSP culvert (56-feet long by 24-inches in diameter with a 0.2-foot elevation difference) and then to a mixing channel (28-feet long by 6-feet wide), which is part of the old alignment of East Benwood Creek. The end of the mixing channel is the confluence with Benwood Creek. The lower basin outlet riser also operates as a circular weir and is fitted with a grease ring made from a 36-inch diameter CSP with 3-inch perforations, like the upper basin grease ring. Submerged orifice flow never occurred at either the upper or lower basin outlet risers.

Figure 7 shows the grease rings in the upper and lower basins empty and partially full, respectively. Figure 8 shows a top view of the outlet riser, grease ring, and trash rack in the upper basin and the outlet riser and grease ring in the lower basin retaining some floatables (conifer pollens).

RUNOFF SAMPLING LOCATIONS AND PROCEDURES

Locations

Figure 2 shows where water samples were collected. Sample locations were chosen in the maintenance yard upstream of the basins to characterize the uncontrolled runoff that previously entered Benwood Creek. To characterize dilution water,

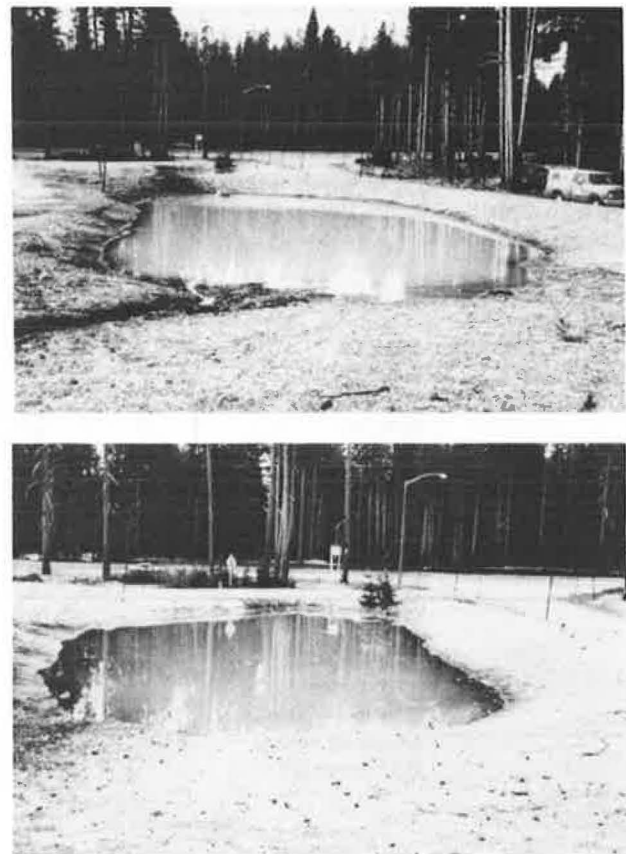


FIGURE 4 (Top) Upper basin. (Bottom) Lower basin.



FIGURE 5 (Top) Old channel basin. (Bottom) Realigned section of East Benwood Creek.

samples were collected upstream in the east and west branches of Benwood Creek. To determine the effect of the basins, samples were collected in Benwood Creek downstream of the lower basin. Sampling was also done to characterize concentrations of water quality parameters in the basins.

Drainage area I consists of asphalt concrete pavement, a salt hopper, a sand storage shed, truck loading areas, and the upper basin. Locations A, B, and AA are just upstream of the upper basin. A and AA are rills just beyond the limits of paving, while B is a sheet flow area on the pavement above the cleanout ramp. (M-surf) is in the overflow jets at the upper basin outlet riser. (M-int) is in the upper basin one foot from the grease ring.

Drainage area II consists of asphalt concrete pavement, are fueling station, and an equipment storage building. Refueling and steam cleaning are occasionally done in area II; however, these activities normally take place at the base maintenance station in South Lake Tahoe. Location F is where runoff from

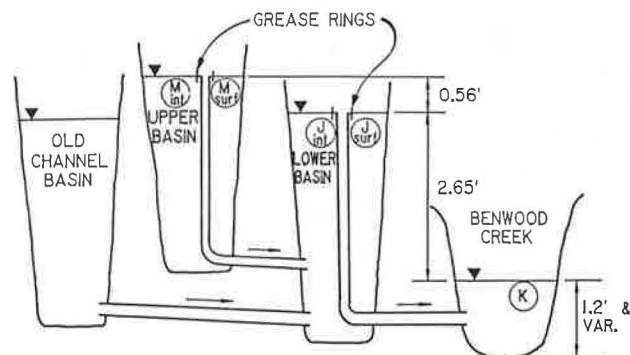


FIGURE 6 Schematic of detention basins.

drainage area II concentrates before it enters the old channel basin.

Drainage area III consists of the access road to the maintenance station and the lower basin. Location I is in the lower basin near the outlet of the 24-inch diameter CSP culvert, the connection to the Old Channel basin. (J-surf) is in the overflow jets at the lower basin outlet riser. (J-int) is in the lower basin one-foot from the grease ring.

Drainage area V consists of wetlands, forest, a small portion of US 50, and realigned East Benwood Creek. Location H is upstream of the maintenance station at the outlet of a 24-inch diameter CSP culvert that conveys East Benwood Creek under US 50.

Drainage area IV consists of wetlands, forest, approximately 0.5 acre of US 50, Benwood Creek, and the confluence of East and West Benwood Creek. Location L is just upstream of the maintenance station in West Benwood Creek, approximately 20-feet upstream of the confluence with East Benwood Creek. Location G is at the outlet of the 24-inch diameter CSP culvert from the lower basin. The waters from Benwood Creek and the lower basin are mixed near G in a transitional mixing channel 28-feet long by 6-feet wide, before the actual confluence with Benwood Creek. The mixing channel is part of the old alignment of East Benwood Creek. Location K is in Benwood Creek, 58-feet downstream of the outlet of the lower basin, 30-feet from the end of the transitional channel, and 42-feet downstream of the confluence of the east (realigned) and west branches of Benwood Creek.

Procedures

All water samples were collected in one-pint glass bottles. A DH-48 depth integrating sampler (2) was used at most locations except at rills, sheet flow areas, and outlet risers. Rills A, AA, and F were sampled manually by immersing the sample bottle in the runoff, specifically avoiding a scooping action.

TABLE 1 DETENTION BASIN DIMENSIONS

Basin	Maximum Length (ft)	Maximum Width (ft)	Maximum Depth (ft)	Side Slopes ^a	Surface Area (ft ²)	Capacity (ft ³)
Upper	83	34	3.5	5:1 (var)	2,360	4,320
Old Channel	112	11	2.3	3:1 (var)	1,070	1,350
Lower	99	40	3.5	5:1 (var)	2,670	6,475

^aHorizontal:vertical.

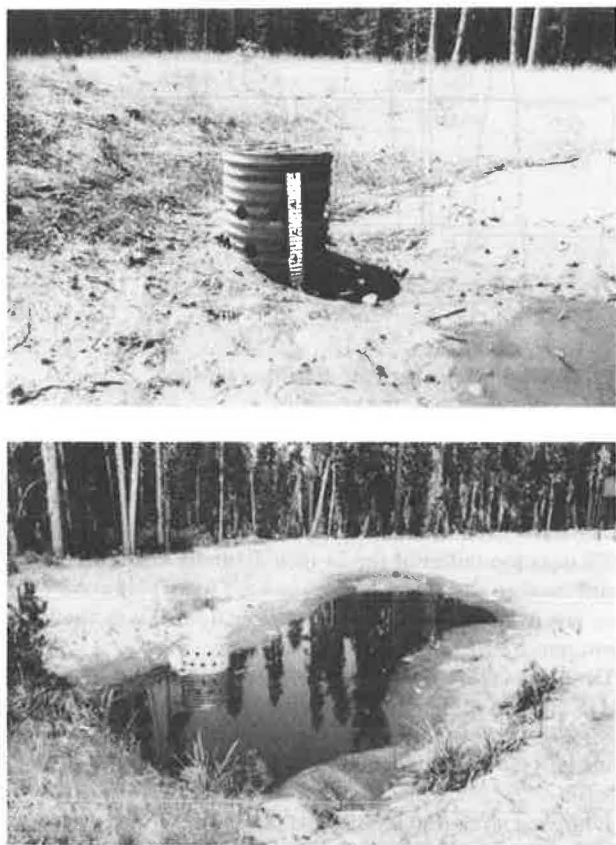


FIGURE 7 (Top) Outlet pipe riser in upper basin. (Bottom) Outline pipe riser in lower basin.

Sheet flow samples were collected at B by using a flexible piece of Plexiglas shaped as a funnel, which intercepted a one-foot wide section of runoff. The samples at (M-surf) and (J-surf) were collected manually by immersing the sample bottles in the overflow jets. All samples were stored in ice chests and brought back to TransLab, where they were analyzed according to test methods in Standard Methods (3).

Instantaneous flow rates were measured using one of the following techniques: velocity-area or time to fill a known volume. Flow rates over the circular weirs at (M-surf) and (J-surf) could not be computed with any of the standard weir formulae, because surface tension effects were observed and the heads never exceeded 0.10 foot.

A sample set consisted of taking at least one pint of runoff (when there was runoff) from each of the 13 locations shown in figure 2, and measuring flow rates. It required less than one hour to traverse the entire site and collect one set of data. The pint samples were discrete, because each of them was collected in about one minute or less. Composite samples (amounts smaller than one pint collected over a longer time until there was a pint of runoff) were not collected, because there were 13 locations, and there were only two people sampling.

Rainfall accumulation was measured with a post-mounted rain gage and was recorded periodically during storms. The gage was installed between the upper and lower basins.

SAMPLING RUNOFF—SPRING SNOWMELT

The 1981–82 water year was wet. The snow depth at Echo Summit was 136 inches on April 8, 1982, approximately 180 percent of normal. Snowmelt occurred gradually because temperatures were lower than normal in May and June (4).

The effectiveness of the detention basins in improving the quality of snowmelt was determined by plotting and analyzing the values of water quality parameters and reviewing the flow rate observations during the spring snowmelt in May 1982. Table 2 is a diary of the sampling dates and comments regarding maintenance activities or other factors that may have affected the water quality. At 9 of the 13 sample locations, normally three (but sometimes two) discrete, one-pint samples were collected at approximately one-minute intervals. Each discrete sample was tested for turbidity, specific conductance, chloride, and oil and grease. Because there were no large differences in values among the one-minute discrete samples, averaged values for each location were plotted (figures 9 through 12) for each sample set.

Turbidity

The detention basins effectively reduced turbidity values. Turbid runoff was due to fine particles being eroded from the stockpiles of sand, cinders, and roadway base material and

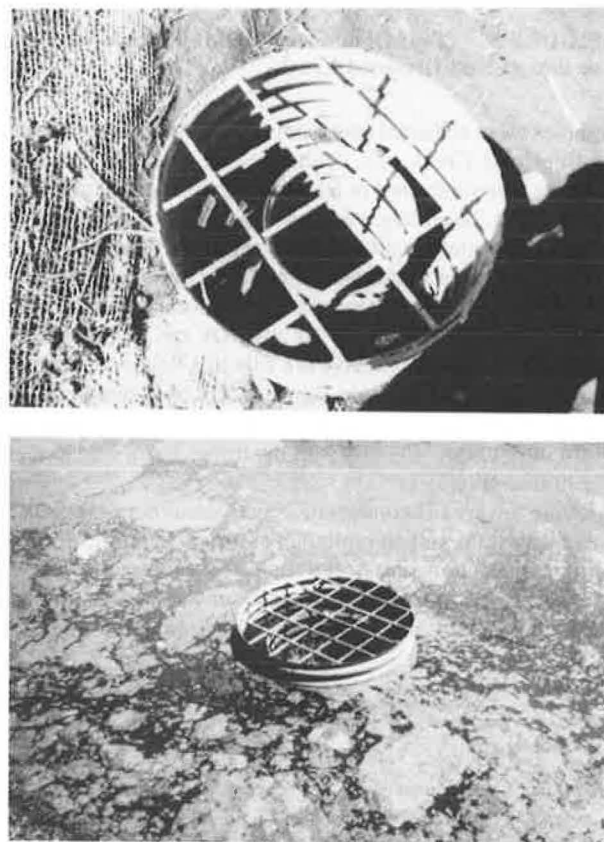


FIGURE 8 (Top) Grease ring, trash rack, pipe riser outlet. (Bottom) Floatables retained by grease ring.

TABLE 2 SPRING, 1982, SNOWMELT DIARY

Sampling Date	Comments
May 3 (AM)	Sunny, no maintenance activity No ice on basins Both basins overflowing Runoff was not measured, but was steady
May 5 (AM)	Five trucks loaded with sand near B (0920 to 1130) Thin ice on lower basin (greenish-colored water) No ice on upper basin (brownish-colored water) Both basins overflowing Silt plume visible in mixing zone G, but not at K Sunny with clear skies Flow rate at K is approximately 6.0 cfs
May 5 (PM)	No ice on any basins No changes in flow rates from AM Scum on lower basin retained by grease ring No maintenance activity during PM
May 10 (AM)	Snow showers previous night, partly cloudy, light snow shower from 1035 to 1045 Three trucks loaded with sand near B Most of snowpack on maintenance yard melted Both basins overflowing Flow rate at K is approximately 6.1 cfs, steady; slight increase over May 5 due to snow showers
May 17 (AM)	Silt plume visible at G, but not at K Partly cloudy No overflow from upper basin to lower basin Lower basin overflowing Thin oil film on old channel and lower basins Flow rate at K is approximately 5.3 cfs, steady Sunny with clear skies
May 24 (AM)	Flow rate at K is approximately 5.8 cfs, steady No runoff from rills at A or AA No overflow from upper basin to lower basin Lower basin overflowing Trout were seen 50 feet downstream of K

from bare soil in drainage area I. Turbidity values at the upper basin inlets (locations A and B) were several orders of magnitude higher than those measured in the lower basin outlet (J-surf) on May 5 and 10. The highest turbidity values occurred at locations A and B when trucks were being loaded with base material. See figure 9.

Fine particles can remain in suspension because there are no baffles or chambers in the basins and because there are relatively short distances from the basin inlets to the outlet risers. The suspended particles are 74 microns (No. 200 sieve) and smaller. The particle size was determined visually by inspecting the water samples in the field and the dried residue in the laboratory using the criterion of the Unified Soil Classification System (5). The values of turbidity were between 20 and 30 nephelometric turbidity units (NTU) at the lower basin outlet (J-surf).

Movement of a silt plume indicated that mixing was occurring in the channel near G. Samples were collected at G during spring snowmelt but not during the fall storms because concentrations in the mixing zone are transitional (6). The focus of this evaluation was to characterize concentrations downstream after mixing with the upstream dilution waters. The east and west branches of Benwood Creek diluted the effluent from the lower basin so that turbidity values downstream at K did not exceed 3 NTU.

Chloride and Specific Conductance

Before the detention basins were built the Forest Service measured chloride concentrations downstream of K in Benwood Creek. Values were greater than 800 mg/l (milligrams per liter).

The source of chloride is dissolved deicing salt, NaCl (sodium chloride), from spillage around the salt hopper in drainage

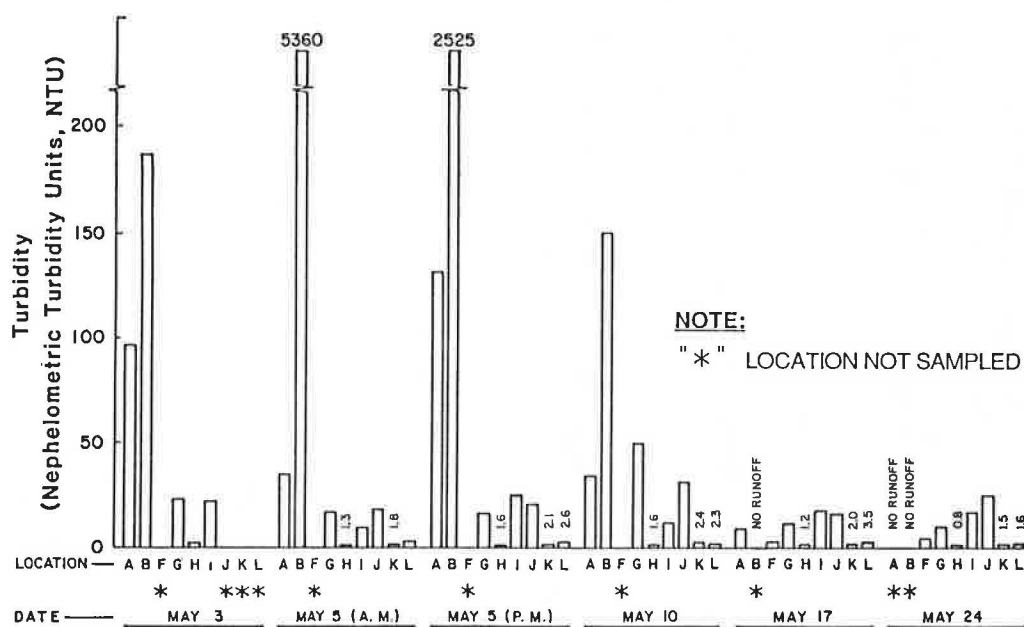


FIGURE 9 Turbidity: Spring snowmelt, 1982.

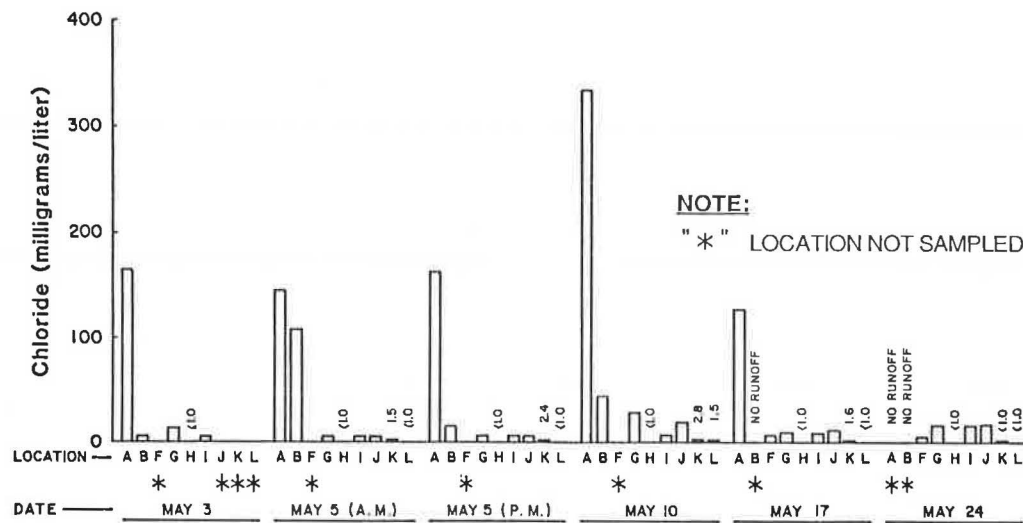


FIGURE 10 Chloride: Spring snowmelt, 1982.

area I. Specific conductance is a measure of the dissolved solids. In figures 10 and 11, when the chloride concentrations were high, so were the values of specific conductance. This indicates that chloride is a substantial fraction of the dissolved solids. Correlations between chloride and specific conductance at locations A and (J-surf) were 0.99 and 0.98 respectively.

The highest values of specific conductance and chloride concentration were at location A, downstream of the salt hopper. Chloride concentrations did not exceed 20 mg/l at the lower basin outlet (J-surf) due to the dilution water from drainage areas II and III. Chloride concentrations were less than 3 mg/l in Benwood Creek at K due to the additional dilution waters from drainage areas IV and V. Chloride concentrations were always less than 2 mg/l upstream in the east and west branches of Benwood Creek (at H and L).

The effluent concentrations at the lower basin outlet (J-surf) are considered not harmful or excessively high. The chloride standard for drinking water is 250 mg/l (7), and the LC50, the lethal concentration at which 50 per cent of rainbow trout die within 96 hours, is 12,200 mg/l (8).

Oil and Grease

The entire maintenance yard (drainage areas I, II, and III) and US 50 (drainage areas IV and V) have potential for oil accumulation and spills. No oil spills were observed during the dates of sampling. Normal maintenance and other vehicular activity was observed at the maintenance station and on the highway.

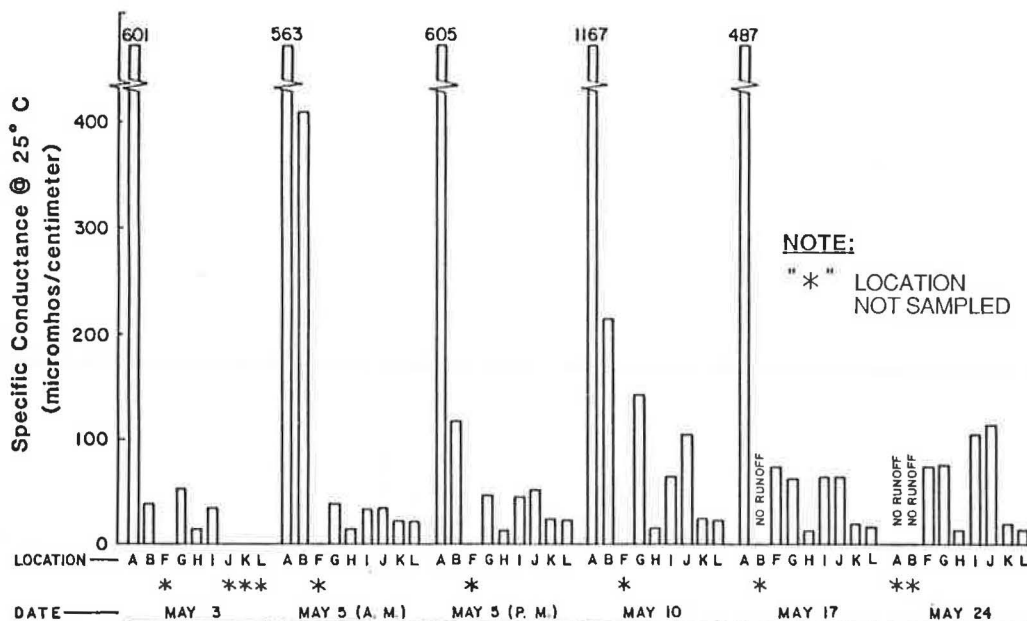


FIGURE 11 Specific conductance: Spring snowmelt, 1982.

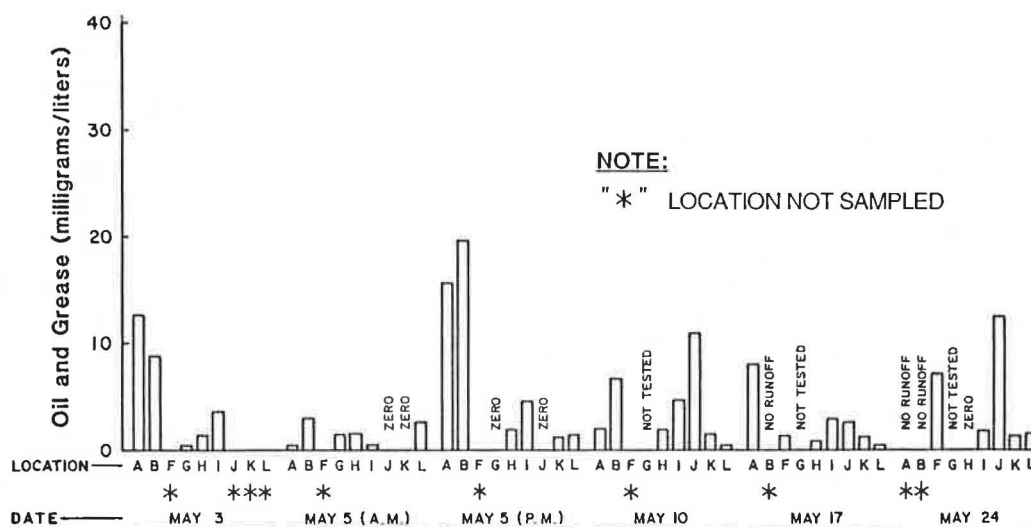


FIGURE 12 Oil and grease: Spring snowmelt, 1982.

The highest oil and grease concentration was 20 mg/l. It was collected at B above the cleanout ramp by the upper basin on May 5 in the afternoon after, not during, the truck loading operation. Concentrations were less than 15 mg/l at the lower basin outlet (J-surf). Concentrations did not exceed 3 mg/l in Benwood Creek at K. See figure 12.

The grease rings appear to retain most of the oil, grease, and other floatables in the lower and upper basins, except during transitional periods. During filling, or as the water level recedes due to infiltration into the ground, some oil and grease or floatables near the risers can flow through the 3-inch diameter perforations and become trapped in the concentric space between the grease ring and the riser. During the next period of overflow trapped substances will be discharged to the creek.

SAMPLING RUNOFF—FALL STORMS

Turbidity, specific conductance, chloride, filterable residue and nonfilterable residue, were measured for samples taken during two storms in October 1982. Oil and grease was not measured for these samples because there was no visible sheen on the water surface. The mitigation effect of the detention basins during storm runoff was determined the same way as for snowmelt, i.e., by plotting and analyzing the values of water quality parameters and reviewing the observations of flow rates, rainfall, and activities during sampling. That information is omitted from this paper for brevity; it is reported in (9). Only one, discrete pint sample was taken for each sample set, because of the small differences found among the one-minute discretely collected during snowmelt and because it took about 45 minutes to traverse the entire site.

There was not enough runoff on October 21 and 22 for the basins to overflow. The basins were about half-full initially, and after the storm they were just short of overflowing. Four sets of runoff samples were collected. A set sometimes consisted of less than thirteen samples when there was no runoff at certain locations. Two sets were collected on the 21st, from the beginning until the end of rainfall (approximately 0.56

inch of rain in 2.5 hours). Two more sets were collected on the 22nd, at which time there were sporadic drizzles that were not measurable.

Both the upper and lower basins were overflowing upon arrival at the site and continued to overflow during the October 25 rainstorm (1.13 inches), which changed to snow (5 inches) during the early hours of October 26. Sampling of runoff (4 sample sets) was done during the first 0.43 inches of rainfall (4.5 hours) on the 25th. The first sample set represented the tail of a rainfall/runoff event that occurred earlier, while the next three sets represented the 0.43 inches of rain. Four more sample sets were collected on the 26th, when there was no measurable snow or rain.

Turbidity and Nonfilterable Residue

Storm runoff samples were analyzed for both turbidity and nonfilterable residue. Values of turbidity and nonfilterable residue were higher on October 21 during the first hour at locations B and H (respectively 39, 29 NTU and 352, 35 mg/l) than during the second hour at B and H (respectively 37, 6 NTU and 42, 8 mg/l). This is called the first flush phenomenon.

It was only drizzling sporadically during the sampling periods on October 22, and there was little or no runoff entering the basins. Turbidity and nonfilterable residue values decreased at H (2 NTU and 1 mg/l) as compared to the values on October 21 during the first hour of rainfall. The basins were not overflowing. Runoff in the three-basin system was infiltrating into the ground, as evidenced by the decrease in water surface elevations from morning to afternoon.

Analysis of the data from the storm on October 25 and 26 showed that values of turbidity and nonfilterable residue were lower at the basin outlets as compared to the basin inflows. At the lower basin outlet (J-surf) values of turbidity and nonfilterable residue were respectively, less than 18 NTU and 19 mg/l and ranged from 5–10 NTU and 3–9 mg/l less than the upper basin outlet (M-surf). Values of turbidity and nonfilterable residue at K (downstream, Benwood Creek) were less than 9 NTU and 18 mg/l.

During the latter two sampling periods on the 25th, the rainfall intensity was greater than 0.1 inch per hour. The nonfilterable residue values at K (12 and 17 mg/l) were slightly higher than at the lower basin outlet (J-surf) (10 and 12 mg/l). Turbidity values did not show this trend. Comparisons of nonfilterable residue at the two other upstream sampling locations, H (<2 and 2 mg/l) and L (<7 and 7 mg/l), could indicate that soil particles between the sample points in drainage area IV were loosened by the intense rain. Alternatively, the sampling technique and the laboratory method may not have been sensitive enough to positively explain these slight differences. The history of concentrations for all other storm runoff sample sets showed lower concentrations of nonfilterable residue at K than at (J-surf).

Specific Conductance, Filterable Residue, and Chloride

The interrelationship of specific conductance, filterable residue, and chloride appears to be consistent. Recall that the upper basin was approximately half-full at the start of the October 21 storm and was just short of overflowing on the 22nd. Thus, the volume of runoff collected in the basins was roughly doubled. The highest value of each parameter occurred in the upper basin at (M-int) during the first hour of sampling. Specific conductance was 1332 micromhos per centimeter, filterable residue was 704 mg/l, and chloride was 389 mg/l. As more runoff entered the upper basin, the concentrations decreased, and by the last sampling period on the 22nd the values of these parameters were respectively, 684 micromhos per centimeter, 340 mg/l, and 191 mg/l, roughly half their initial values.

On October 25 and 26 the chloride concentration did not exceed 40 mg/l at the lower basin outlet (J-surf). The highest observed chloride concentration did not exceed 25 mg/l in Benwood Creek, downstream at K. The corresponding highest values of filterable residue and specific conductance were respectively 67 mg/l and 109 micromhos per centimeter. Values of these parameters at K were correspondingly lower when the basins were not overflowing, indicating that there was not a large amount of dissolved materials generated in areas IV and V during these particular storms.

The relatively large volume of the three detention basins helps to dilute dissolved materials from the maintenance yard. Most of the NaCl came from area I. The data indicated that drainage areas II and III did not produce significant amounts of chloride or other dissolved materials. Dissolved solids in the overflow from the lower basin are further diluted with runoff from areas IV and V.

SEDIMENT ACCUMULATION

The second phase of evaluating the detention basin system consisted of measuring the amount of sediment that accumulated in the upper and lower basins. No sediment accumulation measurements were made in the old channel basin, because drainage area II did not contain any significant sources of sediment. The measurements were performed in September 1982, approximately one year after the basins were built. Sediment sources were stockpiles of sand and excavated materials in drainage area I, spillage from maintenance trucks in

drainage area III, and, predominantly, unstable soil from the sides of the recently constructed basins.

Samples were collected for analysis of grain sizes at various locations in the basins and the creek. The material in the basins was mostly inorganic. Grain size curves are reported in (9). All samples were well-graded and ranged from sandy gravel to silty sand (upper basin), from gravelly sand to silty sand (lower basin), and from sandy gravel to gravelly sand (Benwood Creek). Grain sizes of the sediment samples were compared to particle sizes of snowmelt and storm runoff samples. The basins retain most of the sediment conveyed to them via runoff. Dried samples of nonfilterable residue showed that only particles smaller than 74 microns (200 sieve) escaped from the lower basin.

The amount of sediment retained in the basins was measured by probing through soft sediment to firmer material with a steel rod at several cross sections, when there was approximately 2 feet of water in the basins. Sediment volumes were computed using the average end area method. The amounts of sediment accumulated in one year were

upper basin: 535 cubic feet (12.4 percent full)
lower basin: 1285 cubic feet (19.8 percent full)

The amounts of sediment shown above reduced the design capacities listed in table 1 for temporary water storage. The capacities for water storage before the Fall 1982 storms were 3785 cubic feet for the upper basin, 1350 cubic feet for the old channel basin, and 5190 cubic feet for the lower basin. Thus before the October storms were sampled for runoff, the capacity of the three-basin system was 10,325 cubic feet.

In (9) the same sediment accumulation rates were assumed for future years. It was estimated that the upper and lower basins should be cleaned out every two years. A field inspection and discussion between the maintenance foreman and the author in June 1987 revealed that the basins had not been cleaned out since they were built. There was water in all three basins. No measurements were taken; however it was estimated that the basins were not half-full of sediment. The culvert outlet from the old channel to the lower basin was completely plugged with sediment, and the outlet of the 12-inch culvert from the upper to the lower was 9 inches full of sediment. A South Lake Tahoe maintenance crew cleaned the culverts in early November 1987.

BIOLOGICAL REVIEW OF BENWOOD CREEK

The third phase of evaluating the detention basin system consisted of assessing the aquatic habitat of Benwood Creek. The objective was to determine the biological potential of the creek and to estimate the effect of constructing the detention basins and channel realignment. The assessment was made in September 1982, one year after construction by a TransLab aquatic biologist and a US Forest Service hydrologist. At that time the flow in Benwood Creek appeared normal, approximately 1 cfs, and no snow was present.

The bottom of the realigned section of East Benwood Creek is rock rubble (average size from 2 to 4 inches) and is covered with fine silt. Unlike the bog, which has a dense cover, the rechanneled section is exposed. At the end of the rechanneled section, the stream passes through a second steel culvert before

entering the old streambed. The old bed is composed of an alternating series of runs and deep pools. Vegetation covers the banks, but some stretches of the stream are exposed during midday. Bottom sediments were rock cobble in the runs and silt and sand in the pools.

The water leaving the bog is acidic and brown, which indicates large amounts of organic acids. There was no change in temperature within the bog. If there is any aquatic life in this area none was observed, due to the small channels and dense vegetation.

In the rechanneled section, especially near the culvert under US 50 and sampling location H, there was reddish brown floc on the cobbles. The floc was caused by the precipitation of iron, probably as ferric hydroxide in association with iron bacteria. Several different types of aquatic insects were observed; however, a single species of chironomid larva was more prevalent than any other species. The water temperature increased several degrees in the rechanneled section.

In the old streambed the organic acid content was sufficient to color the water; however iron precipitation was not evident. Many different species of aquatic insects were observed in the streambed and leaf litter.

Benwood Creek seems typical of streams originating in spring-fed bogs in noncalcareous soils. The precipitation of iron and the low pH are characteristic of such streams. The increase in temperature and presence of large numbers of single species in the rechanneled area is due to the construction, not to pollution from the maintenance yard. The condition of the aquatic habitat in the rechanneled area is highly disturbed due to the construction and is just beginning to stabilize. The condition of the aquatic habitat above and below the rechanneled area is not significantly different from any other mountain stream originating in a similar bog. By November 1987 the surviving trees and shrubs that were planted on the berms and along the rechanneled section appeared to be growing slowly.

CONCLUSIONS AND FINDINGS

The detention basins effectively reduced turbidity values from the maintenance yard runoff during conditions of snowmelt and storm water runoff. Turbidity values measured at eroded areas and paved ramps leading into the basins from the maintenance yard were greater than those in Benwood Creek by two, and sometimes three, orders of magnitude. Downstream values in Benwood Creek did not exceed 10 nephelometric turbidity units (NTU). Turbidity values measured downstream of the maintenance yard in Benwood Creek were only slightly greater than those measured upstream of the detention basins.

Shock loadings of nonfilterable residue in Benwood Creek from maintenance yard runoff will be mitigated, as long as there is capacity for runoff and as long as accumulated sediment is periodically removed from the basins and the interconnecting culverts. Concentrations of nonfilterable residue did not exceed 20 milligrams per liter (mg/l). Particles of sediment smaller than 74 microns (No. 200 sieve) can remain in suspension and can flow through the lower basin into Benwood Creek.

The old channel and lower detention basins did not produce large amounts of chlorides, thus the runoff collected by them

diluted dissolved materials and NaCl deicing salts from the upper basin. Chloride concentrations in Benwood Creek were below 30 mg/l as compared to approximately 800 mg/l before the basins were built.

The grease rings, which were fitted around the outlet risers, appeared to prevent most of the oil, grease, and floatables from escaping the basins. During the transitional period (filling or emptying), oil and grease or floatables near the risers can flow through the 3-inch diameter perforations and become trapped between the grease ring and outlet. The trapped substances will flow through the outlet during the next overflow event. Oil and grease concentrations from the maintenance yard during snowmelt were approximately 20 mg/l, while values in Benwood Creek upstream and downstream of the basins did not exceed 3 mg/l.

Measured snowmelt rates were 2 to 5 times greater than storm runoff rates. Snowmelt produced steady, gradually changing flows as compared to unsteady, rapidly changing flows from rainstorms.

The runoff detained in the three basins ultimately infiltrates into the ground and/or evaporates.

The basins are expected to remain aerobic, since they are shallow (less than 3.5 feet deep when full), and they will remain aerobic as long as they do not receive large amounts of decaying leaves or any human or animal waste.

Basin cleanout schedules are not easily forecasted. Original estimates showed that the basins would need to be cleaned out approximately every two years. After almost six years of operation there appears to be adequate volume for retaining sediment in the basins; however, the interconnecting culverts needed to be cleaned so the basins could function as they were designed.

The biological assessment indicated that the aquatic habitat in the realigned channel was highly disturbed but was beginning to stabilize. The condition of the aquatic habitat upstream and downstream of the realigned channel was not significantly different than any other mountain stream originating in a similar bog.

RECOMMENDATIONS AND APPLICATIONS

Maintenance yards should be inspected to determine if drainage from the yard is affecting nearby streams, lakes, or other bodies of water. It is usually not a trivial task to assign a dollar value to mountain streams and their supporting watersheds. Building and operating a maintenance station without consideration or protection of nearby water resources can destroy the valuable uses of the water and may lead to regulatory agency enforcement actions. When impacts are found or potential impacts are identified, a detention basin system should be considered as a mitigation measure.

A properly designed, constructed, and maintained detention basin system can effectively reduce the turbidity levels and sediment loads from maintenance yard runoff. Drainage areas, levels and kinds of maintenance activities, and the uses of nearby receiving waters must be studied before sizing and locating basins. The distance between the outlet of the basins and the major points of inflow should be as long as possible. Baffles should be considered for situations where berms cannot be used to prevent inflows from going directly to the outlet. Baffles reroute primary inflows, reduce turbulence,

and inhibit resuspension of fine particles already deposited in the basins.

If oil and grease or other floatables are not wanted or allowed in the effluent, a floating, sorbent boom can be installed around grease rings. The floating boom will absorb and block oil and grease and other floatables from escaping the basins during the periods when the water level in the basins is fluctuating and near the level of the perforations in a grease ring. Floating sorbent booms must be changed periodically.

The materials used to construct the outlet structures of basins, e.g., weirs or spillway aprons, should be nonerosive to prevent nonfilterable residue from entering the effluent.

Generally, when a basin becomes half-full of sediment, it should be cleaned out to provide more volume for dilution and to maintain trap efficiency. The outlet risers should be banded or clearly marked at the half-full level when the detention basins are first built, so that a simple visual inspection will show how much sediment has accumulated. A minimum of one inspection per year is suggested, when the basins are mostly dry.

Culverts that interconnect basins and outlets should also be inspected annually and cleaned when they are more than 50 percent plugged. When it is feasible, the outlet elevations of the interconnecting culverts should be constructed such that the flow lines are at the half-full level of the basin.

Maintenance yards should be kept clean. Spills of salt, sand, and cinders around bunkers and in the yard should be cleaned-up before storms. Where it is feasible, diked and/or covered areas can be used to contain materials in the yard. Frequent cleanups will help prevent these materials from entering the runoff in the first place.

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