Results of Monitoring King County Wetland and Stream Mitigations

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of

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EXECUTIVE SUMMARY

Forty mitigation sites in King County were monitored to evaluate success against performance standards, which were typically: 80% emergent cover; 45%-75% shrub and tree cover; and 80% survival rates by year three. Nine mitigations had not been installed, leaving 31 sites. Two were excluded because they were less than three years old. Thus, 29 sites comprise the study group.

Within the study group, 6 sites (21%) were successful by then-current performance standards, 23 (79%) were not. One site (3%) replaced functions of impacted wetlands, 28 (97%) did not. Based on this sample group, significant net loss of wetland and stream habitat is occurring in King County.

Causes of failure included: design, installation, and maintenance. Design flaws include: hydrology inputs not as represented in design; plants inappropriately specified; and slopes steeper than 3:1. Installation flaws include: not installed as designed; soil compacted (especially where steep slopes required compaction for stability); and no organics, i.e., soil not amended as designed. Maintenance flaws include: mowed; not weeded; and not mulched or irrigated during establishment year.

Monitoring forms had not been designed to note the following common ingredients of failure: inappropriate design, including insufficient hydrology as a result of design or construction oversights; slopes steeper than 20%, and plants specified for inappropriate habitat; compacted soil without organics; and lack of maintenance.

Proposals to increase mitigation success include new requirements and guidelines for mitigation plans, and new inspection procedures. New design requirements include: demonstrated hydrologic calculations; plants specified for micro-habitat, guided by new habitat worksheet; no slope in wetland steeper than 10%, and no buffer steeper than 20%; soils on all sites to be deconsolidated and amended with organic matter; and specific limits on exotic plants. New installation requirements include: elevations and soil preparation must be inspected before plants are installed, and plant installation must also be inspected. New maintenance requirements include: signed monitoring and maintenance contracts over a five-year monitoring period that follow new maintenance and monitoring guidelines, or similar sureties.

The new inspection schedule calls for inspections before installation (pre-construction); after soil decompaction and amendment, or grading if called for (construction); and after plant installation (installation), as well as yearly inspections to verify monitoring reports.

INTRODUCTION

Review of the Literature: The most recent comprehensive review of research into wetland mitigation success in the Pacific Northwest is "Wetlands Mitigation Replacement Ratios: Defining Equivalency" (Castelle et al., 1992). Common causes of failure nationwide are "inadequate design; failure to implement the design; lack of proper supervision; site infestation by exotic species; grazing ...; destruction by … catastrophic events; failure to adequately maintain water levels; and failure to protect projects from on-site and off-site impacts..." (Kusler and Kentula, 1990). Additionally, in the Pacific Northwest, Miller (1987) cited "improper final grade, non-native plant species substituted for native species, improper planting techniques, inadequate water levels, human impacts, and wildlife predation" as common causes of failure.

Sheldon and Dole (1991) studied five sites in King County and three in Snohomish County to determine if wetland mitigation sites met their performance goals. They concluded that most sites were too young to determine if they were functionally equivalent to impacted wetlands, and that performance goals lacked quantifiable measures of success.

Background: This paper uses Castelle's (1992) terminology — "mitigation" refers to compensatory mitigation: the creation, restoration, or enhancement of unavoidable wetland impacts. This is the last step in mitigation sequencing after avoidance, minimization, rectification, and reduction.

King County Department of Development and Environmental Services (DDES) regulates building activity within unincorporated King County. DDES can allow mitigation as a permit condition for altering existing wetlands, as codified in the Sensitive Areas Code found in KCC 21A.24. Such mitigations are typically secured by performance bonds held for a three to five year monitoring period. In October 1997, Anna Mockler was hired by DDES to monitor wetland mitigation projects, and to reduce or release all bonds that satisifed performance standards.

Performance standards generally focus on vegetation, which is assumed to improve water quality by trapping sediment and transforming toxins, and to provide wildlife forage and habitat. Typical performance standards since 1991 are: 80% emergent cover; 45%-75% shrub and tree cover; and 80% survival rates, all by year three. Note that quantifiable measures of success were introduced gradually after 1991.

Since DDES is a regulatory agency, sites were monitored for compliance with permit conditions. Where sites are out of compliance, corrective actions are required against the possibility of bond forfeiture. Bonds typically state that DDES will perform the work if the applicant doesn't, and he or she is liable for the full cost of such work. Thus, unlike most monitoring programs, DDES has the potential to follow up and correct deficiencies. Further, monitoring results can feed back directly into mitigation plan guidelines and review.

METHODS

Monitoring forms and protocols from "Monitoring Wetlands" were used (Miller et al., 1996). Typical protocols measure vegetation survival and areal coverage, since these are the basis of performance standards, as well as hydrology, soil, wetland and buffer condition assessment, wildlife habitat, and invasives. During a typical site visit, appropriate monitoring forms were filled out, and additional information entered into a field notebook. Later, a report was sent to the bond-holder that summarizes observations, synopsizes the monitoring forms for the lay reader, and outlines corrective actions. Information was entered into a custom-made database that generates reports and organizes data.

Sites were inspected in two hierarchies: those who requested inspection came first, and other sites were inspected in the order they were installed, i.e., commencing with the oldest.

As of April 1, 1998, consistent field data was available for 40 mitigation sites. For site-specific details of selection and results, see Appendix A. Two sites were rejected for this study as they were not due to be installed until 1996. Nine were rejected since, though due to be installed, they had not been installed. Twenty-nine sites were left. All 40 sites are less than one acre, excepting #18, which is 3.26 acres.

RESULTS

Of 29 installed mitigations in the study group, 23 (79%) failed, and 6 (21%) succeeded by performance standards. Had the 9 mitigations which were not installed been included, which is how DDES views the matter, failure rate would have been 84% (32 of 38). One of 38 (3%) succeeded in replacing functions of impacted wetlands, while 37 did not (97%).

Of the 23 failed sites, 15 (65%) were created wetlands; four (17%) were restored wetlands or buffers; and eight (35%) were enhanced wetlands or buffers. The total is 27 because most sites consist of creation — a small pool graded for open water and emergents — *and* enhancement, typically of wetland buffer, or some other combination. Most sites were classified according to the dominant mitigation type, but on some this was impossible. Fifteen (65%) were in subdivisions; four (21%) were residential lots; four (21%) were associated with commercial developments. See Table I in Appendix A for details.

Successes: Of the successes, 50% succeed by virtue of their performance standards alone. One called for installation of Himalayan blackberry *(Rubus discolor)*, which is doing well. One had no restrictions against invasives, which dominated the site. The third had to be deemed successful because County facilities maintenance was mowing it as a stormwater management facility.

The remaining 50% had some success in replacing lost functions. One was a 1000 sq. ft. created emergent wetland at the outlet of a stormwater pond. The other two had consistent riparian hydrology — one expanded an oxbow with emergent plantings, and one actually replaced the impacted wetland. See Appendix A for details.

Failures: As Table I in Appendix A states, flaws fell into three general categories: design, installation, and maintenance. Design flaws are sub-divided into hydrology, wrong plants, and steep slopes. Installation flaws are sub-divided into not as designed, compacted soil, or soil lacking organic matter. Maintenance flaws are sub-divided into mowed, not weeded, or lacking mulch or irrigation.

Of 23 mitigation sites, 16 (70%) had design flaws. Of all 23, 14 (61%) plans had inaccurate notions about how much water would be delivered to the wetland. Fifteen (65%) had chosen the wrong plants for the site — either shade-dependent plants crisped in full sun, or wetland (obligate or facultative wet) plants suffered on dry buffers. Eleven (48%) had slopes 3:1 or steeper, and there was no interaction between wetland and upland.

Of 23 sites, 20 (87%) had installation flaws. Of all 23, 13 (57%) were not installed to design — either elevations were not as designed and/or plants were not installed as designed. Seventeen (74%) suffered from compacted soils, either because they had been graded to subsoil or compacted by heavy machinery — note that every site that suffered from steep slopes also had compacted soil in order to retain their unnatural angle of repose. Seventeen (74%) lacked soil organic matter.

Of 23 sites, 21 (91%) had maintenance flaws. Of all 23, 11 (48%) were mowed. Sixteen (70%) were never maintained at all. Fifteen (65%) were not mulched or irrigated during establishment. Many sites suffered from dumping of yard waste and other debris, and many had suffered encroachments from neighboring land-owners, including swing sets and non-native plantings.

Of 15 created wetlands, 14 (93%) had design flaws; 15 (100%) had installation flaws; and 13 (87%) had maintenance flaws. Of four restored wetlands and buffers, none had design flaws; all had installation flaws, specifically not installed to design; and all had maintenance flaws. Of eight enhanced wetlands and buffers, three (37%) had design flaws; five (62%) had installation flaws; and all had maintenance flaws.

Of the 15 created mitigations, which suffer most from design flaws, three (20%) were just bioswales with shrubby buffers, all an unnatural mix of wetland and sub-canopy shrubs (hereinafter, PSS*); two (13%) were relocated streams; two (13%) were expansions of existing emergent or scrub-shrub wetlands; one was a created emergent wetland designed to be fed by stormwater inputs; one was a regraded buffer; and five (33%) were stormwater systems composed of retention/detention ponds, (sometimes called emergent wetlands), bioswales, and PSS* in the buffer. With the exception of the bioswales, all lacked designed hydrology (87%), and the expansions suffered worst.

Of all mitigations, 15 of 23 (65%) employed PSS*, which enjoyed particularly high mortality and stunted growth, with cover generally less than 20%, and often less than 5% after three years.

DISCUSSION

A 79% failure rate — 84% if DDES view is used, and 97% if functions of impacted mitigations are compared to their replacements, is a sad picture. If the average rate of compliance with permit conditions is 50% (Castelle et al., 1992), then King County compares poorly.

A useful mnemonic for causes of mitigation failure is: Sun, slope, soil, specifications, stewardship. The following discusses this in more substantive detail.

Design:

In reviewing design flaws, we note few or none in design for restoration. There are more flaws in enhancement plans, and virtually every plan that calls for wetland creation is flawed. This parallels the results in the literature (Garbisch, 1986; Castelle et al., 1992). We have gained some knowledge of what works on the ground through experience, and have learned what information is required by reviewers in order to properly estimate and achieve successful mitigation plans.

We have learned that retention/detention ponds and other stormwater systems can't duplicate wetlands when they are maintained primarily as stormwater storage facilities, i.e., mowed and gravelled. Bioswales are often invaded by reed canary grass. Most importantly, we have learned that a hydrologic budget sufficient for one wetland can't supply wetland expansion simply by grading additional acreage down to the level of the original wetland.

To create wetlands, topographic contours of 6" to 12" (including spot elevations), detailed hydrologic budgets, and biological benchmarks are required (Garbisch, 1990) — in no study site were these three elements available to reviewers. Without that information, thoughtful review of mitigation plans is impossible. Without high-definition contours, steep slopes can be slipped into design, and will be, since they give the largest possible mitigation area in the smallest amount of valuable real estate. Without elevations and a hydrologic budget, structural design, e.g., control structures, can't be effectively done. Without all three elements, plants can't be specified for appropriate water regimes.

We also need to be informed of surrounding conditions. If a small wetland is to be created in the middle of a forested area, then shade-dependent plants are a suitable choice. If a wetland is to be installed in the middle of an urbanized area, among residents only familiar with traditional landscaping, then protective safeguards (fences) and signage need to be in place. If a small defenseless wetland is to be created or restored in the middle of a carnival of exotic species, then additional maintenance requirements need to be imposed.

DDES recommended planting densities were too low to achieve performance goals within three years in the absence of excellent hydrology. Densities of trees 3'-4' in height,12' OC (on center) and shrubs 2'-3' in height, 9' OC were recommended, which may correspond to densities of mature systems, but do not mirror the early stages of succession towards maturity. Further, these are bare-root standards, whereas root growth, or container size, is a more accurate measure of plant age and vigor (Buis, 1998).

Note that densities were allowed to be halved if woody vegetation twice the size was installed. Native plants have much higher success rates if installed at smaller sizes, where they can adapt to site-specific conditions (Alfriend, 1993; Buis, 1998; Sheldon, 1998).

Other researchers have noted that aesthetic values are rated high in most urbanized wetland mitigations (Sheldon & Dole, 1991; Garbisch, 1986). This is probably why the unnatural mix of wetland and sub-canopy shrubs, or PSS*, are found in many plans. Everybody loves shrubbery, which doesn't block views or pose the hazards of trees. Since the Northwest has few native shrubs that are neither water- nor shade-dependent, shrubs planted in dry buffers and full sun have very high rates of failure.

Recent findings indicate that herbaceous emergents are an important component of all wetland plant communities (Horner et al., 1996). These were seldom, if ever, included in mitigation design. Hydroseeding with tall non-native grasses is often called for, which can out-compete small shrubs, and may literally bend them to the ground.

Design errors could be corrected by requiring more information in mitigation plans, and by more stringent requirements for such plans, based on our new knowledge.

Installation:

In reviewing installation flaws, over half exacerbate design problems — slopes are made even steeper, and plants are placed or selected even more inappropriately. Compacted soils without organics were found on three-quarters of all mitigations — even with excellent hydrology, which designs often assume, if soils don't have the organic content of natural wetlands (Azous et al., 1998), plants will suffer. If soils are compacted, plants will grow to the edge of their amended planting pit, and then die back or fall over, usually in the second or third year. Some non-native species or varieties were used.

Mitigation plans call for the supervision of a qualified biologist during construction, but there was seldom evidence that this occurred. Requirements for soil amendation and decompaction were generally included in plans, but were not performed in the field.

Installation errors could be corrected by requiring DDES inspections and by documentation, e.g., receipts for soil amendments, machinery and labor for decompaction, nursery invoices, and references from installation contractors who had previously installed successful sensitive area mitigations, etc.

Maintenance:

In reviewing maintenance flaws, it is most striking that not one of the failed sites was maintained. Where mowed, they were not mowed to keep down invasives and strangling grasses, but without discrimination, resulting in mowing of planted species. None had controlled Himalayan blackberry. As a result, some sites had over 75% blackberry cover. This is probably exacerbated by the fact that quite a few King County residents and consultants believe them to be native plants. The result is that planted species are outcompeted by invasive exotics.

Sites were generally neither irrigated nor mulched during the first year of establishment. Much of this can be attributed to the general belief among reviewers and installers alike, and one originally shared by the author, that native plants don't require special attention, whereas this is only true after establishment (Alfriend, 1993; Casey et al., 1996). The result is stressed plants that often die after their first year. Landscape contractors typically guarantee plants for one year, which is not that difficult to achieve — in fact many of these sites passed inspection at that time — but to persist and thrive, a nourishing childhood is as important to plants as to people.

Maintenance errors could be corrected by requiring monitoring and maintenance contracts, or other sureties, and by annual DDES site inspections to verify monitoring reports.

Other:

Field observations support Cowardin et al. (1979) — semipermanently to permanently flooded wetlands are dominated by emergents, e.g., sedge meadow; seasonally to semipermanently flooded wetlands are dominated by shrub cover, e.g., willow/hardhack; while most mitigation sites are, at best, temporarily to seasonally flooded, a regime that should support forested wetlands.

It was observed that succession in forested wetland mitigations typically progressed from FAC dominants (alder, cottonwood) to FACW and OBL dominants (cedar, salmonberry, skunk cabbage). Using Occam's Razor (the simplest is likeliest the best) to select alternatives, it is proposed that such mitigations be designed to mimic the recovery process where openings are created in wetland forests, e.g., densely planted to seral species like alder, willow, cottonwood, and Douglas fir, with an understory of robust, sun-tolerant natives like thimbleberry and lupine. After three years of growth, the site would be underplanted to a more diverse assemblage including cedar, hemlock, yew, and appropriate shade-dependent shrubs, forbs, and ferns. The DDES publication "Sensitive Area Mitigation Guidelines" explains this in detail.

RECOMMENDATIONS

New mitigation guidelines have been written, reviewed, and approved by all the authors, who are employees of King County. The full text of the sensitive area guidelines can be obtained from DDES. Some selected highlights follow:

Sensitive Area Mitigation Guidelines

- 1' contours on most projects, and 2' contours on minor projects;
- Four cross-sections per 1/4 acre showing existing and proposed grades in 1' contours;
- Existing and proposed hydrology for inflows, outflows, basin, and HGM type;
- Existing trees more than 18" dbh and other surrounding conditions;
- Legible, readily understandable planting keys and plans guided by Mitigation Guidelines;
- Outline of a monitoring plan guided by Monitoring Outline and copy of signed monitoring contract;
- Non-native plants limited to 10% cover in any strata in any monitoring year;
- Outline of a maintenance plan and copy of signed maintenance contract;
- All plants must be native to Puget lowlands of western Washington;
- Shade-dependent species (as defined by Mitigation Guidelines) to be specified only where shade exists at time of planting;
- Plant selection and placement guided by habitat needs (see Mitigation Guidelines);
- Soils must be deconsolidated to at least 12" for woody vegetation, and 6" for emergent vegetation;

- Soils must be amended with, typically, 2” of coarse builder’s sand and 4” of organic compost;
- Demonstrated hydrologic calculations for impacted and replacement wetlands;
- No slope in buffer may be steeper than 20% (5:1);
- No slope in wetland may be steeper than 10% (10:1);
- Most mitigations must be protected by a permanent fence at least 4’ high, with Sensitive Area signs erected every 100’;
- Regular inspections before, during, and after plant installation;
- Every plant must be replaced during Year One after installation;
- During Year One, and during the first year after any replacement planting, plants must receive at least 1” of water per week June-September;
- Through monitoring period, weed to dripline and maintain mulch at 3” depth, semi-annually;
- Remove all litter, dumping, and non-native vegetation, semi-annually;
- Repair or replace all damaged or missing structures, semi-annually.

Wetland and Buffer Mitigation Guidelines:

The following recommended planting densities do not comprise the entirety of the Guidelines:

I. Emergent (PEM) wetlands (FAC, FACW, or OBL species) are to be planted to:

A. Emergents 1’ O.C., or one per square foot of area (this assumes 10” plug or 4” pot); OR

B. 2’ O.C., or 0.444 per square foot of area, if supplemented by overseeding of native emergents or graminoids as appropriate.

II. Shrub (PSS) wetlands (FAC, FACW, or OBL species) are to be planted to:

A. Shrubs 5’ O.C., or 0.04 per square foot of area; (this assumes 2 gal. size);

B. Plus herbs and groundcovers 4’ O.C., or 0.063 per square foot of area; (this assumes 10” plug or 4” pot);

C. Plus overseeding with native emergents, graminoids, clover, or sterile wheatgrass (ReGreen©) as appropriate.

III. Forested (PFO) wetlands (FACU- to FACW species) are to be planted to

A. Either:

1. Trees 9’ O.C., or 0.012 per square foot of area; (this assumes 2-5 gal. size) — such trees are to be at least 50% conifers;
2. Plus shrubs 6’ O.C., or 0.028 per square foot (this assumes 1-2 gal. size);
3. Plus herbs and groundcovers 4’ OC, or 0.063 per square foot of area (this assumes 10” plug or 4” pot);
4. Plus overseeding with native emergents, graminoids, clover, or sterile wheatgrass (Regreen©) as appropriate.

B. OR: The Simple, Two-Step Process

1. Plant alders, cottonwood, willows (other seral species, e.g., big-leaf maple, Doug fir, as appropriate to site) at densities of 8’ O.C., or 0.016 per square foot (assumes 2 gal. size); plus overseed with clover, sterile wheatgrass (ReGreen©), low-growing non-invasive grasses, lupines, etc.;
2. **After three years of greater than 85% survival, underplant with:**
3. Conifers (Sitka spruce, cedar, hemlock, yew, Doug fir in a wetter-to-drier continuum) 12’ O.C., .007 per square foot of area, (this assumes 2-5 gal. size);
4. Plus shade-tolerant or dependent sub-canopy species (Indian plum, vine maple, etc.) 9’ O.C., .012 per square foot of area (assumes 1-2 gal. size);
5. Plus shade-tolerant and dependent herbs and groundcovers (waterleaf, trillium, *Smilacina*, etc.), 4’ OC or 0.063 per square foot of area (assumes 10” plug or 4” pot), plus overseed with native herbs and grasses.

IV. Buffers

A. Are to be planted as for Forested Wetlands, except:

B. Species are to be UPL to FAC, instead of FACU- to FACW.

C. See Site Placement in Habitat section — best species for this area are those marked WB (wetter buffer) and DB (drier buffer)

CONCLUSION

Mitigations are not being installed. Those that are installed have high rates of failure. Failure can be separated into design, installation, and maintenance flaws. Created wetlands suffer worst from design flaws, but inexact hydrology, inappropriate plants, and overly steep slopes are found among all mitigation types. Installation flaws can exacerbate design problems, but the most common flaws are inadequate soil preparation and failure to install as designed. Maintenance is the most common flaw — most mitigations are installed and not properly maintained, leaving them prey to invasive exotics and mowing. We must change the way we regulate, design, review, implement, and inspect wetland and stream mitigations.

Many of this report's recommendations are similar to those made by Sheldon and Dole in their 1991 report. They noted that time would tell. It has told, and in the light of that new knowledge, with the implementation of new requirements and guidelines, we hope and expect that three years from now we will be able to report much higher percentages of mitigation success.

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Appendix A

Details of Site Selection and Results

As of April 1, 1998, consistent field data was available for 40 mitigation sites. Two sites (39 and 40) were rejected for study purposes because they were not due to be installed until 1996; nine sites (1,5,7,10,15,17,23,35,38) were rejected because they had not been installed. Twenty-nine sites were left. All 40 sites are less than one acre, except #18, which is 3.26 acres.

RESULTS

Six (21%) mitigation sites succeeded by performance standards (6, 8, 12, 19, 25, 27). Nineteen (66%) mitigation sites were failures over >60% of area (2, 3, 4, 9, 13, 14, 16, 18, 20, 22, 24, 26, 28, 29, 30, 31, 32, 33, 37). Four (14%) mitigations failed under 40% of area (11, 21, 34, 36). Of all mitigations in the study group of 29, 79% failed. Of 38, nine were not installed (1, 5, 7, 10, 15, 17, 23, 35, 38) — three of these (10, 17, 38) failed completely after initial installation; replacement plantings were required but not installed, and these are described among the failures.

Successes. A review of the successes shows that only two (25, 27) would have succeeded under current performance standards. Four (6, 8, 12, 19) succeeded by then-current standards.

#6 is a buffer enhancement that succeeded by its mitigation plan's standards, which called for the installation of Himalayan blackberry *(Rubus discolor)* cuttings treated with root hormone, and red alders *(Alnus rubra)*. This mitigation has achieved good dense cover.

#8 borders the Sammamish River, with good perennial hydrology, and its emergent wetland has excellent cover. Though reed canary grass *(Phalaris arundinacea)* has over 60% cover, and cattail *(Typha latifolia)* has over 35% cover, there were no specifications in the mitigation plan against invasives, native or exotic.

#12 is a retention/detention pond in the middle of a subdivision surrounded by a good stout plank fence. Hydrology in the ponds is consistent, fed by stormwater runoff and maintained at pool level by County stormwater drains. Thick stands of *Polygonum* spp. cover their surface, with cattails and small-fruited bulrush *(Scirpus microcarpus)*. Buffers are thick with the specified exotic *Rosa rugosa*. Cover standards couldn't be enforced in the buffer, because King County Facilities Maintenance mows them. A great blue heron foraged in the tall adjacent cottonwoods.

#19 has near-perennial hydrology from a channelized stream that is temporarily dammed against the foundation pilings of a small subdivision and forms small pools in the created emergent wetland before water exits into a culvert. Emergent and scrub-shrub wetlands are vigorous throughout. Channel shrubs and trees are on steep slopes but appropriate to their water regime. Invasives form less than 15% cover since creeping buttercup *(Ranunculus repens)*, was not so identified in the approved mitigation plan.

#25 is the only mitigation site in the study group that actually replaces functions of the impacted wetland — a small riparian slough of a near-perennial low-gradient stream. This area was cleared to the gravel before mitigation. It was planted to slough sedge *(Carex obnupta),* small-fruited bulrush, alders, elderberry *(Sambucus racemosa),* redcedars *(Thuja plicata)*, hemlocks *(Tsuga heterophylla)*, Douglas fir *(Pseudotsuga menziesii)* etc. The owners have maintained the mitigation and continually under-planted with salvaged material from nearby developments, sword ferns *(Polystichum munitum)*, salal *(Gaultheria shallon)*, and seedling conifers. After four years, this site has 80% shrub and tree cover, with emergent cover of over 90%.

#27 created 1,000 sq. ft. of wetland near the outflow of a two-cell retention-detention pond. Slough sedge, small-fruited bulrush, and water parsley are doing well in partial shade. This is the only observed mitigation where Oregon ash plantings succeed and reproduce. Buffer was enhanced with conifer plantings.

Failures

Failures over 60% of area: These mitigation sites typically failed over more than 85% of area, and their causes are more analytically displayed in Table 1.

#2 was successful at the one portion that was previously inspected: the buffered outlet of an R/D pond. The rest of the mitigation was apparently never installed. Where there was shade, about 40 new plants were thriving, whether volunteer or installed could not be determined. Where there was full sun, on either side of the bioswale, a few mowed shrubs were found at the base of a 2.5:1 slope, and none on the slope itself. The swale was dominated by reed canary grass. Sediment fence was still in place, home-owners' encroachments into the buffer were found, and dumping was found throughout the mitigation site and the original wetland.

#3 had such dense Himalayan blackberry cover that the full extent of plant survival or cover could not be properly estimated. One portion was never planted because an inaccurate survey placed an appropriate buffer around the relocated stream, but that buffer was later found to occupy a home-owner's lot. A created wetland called for in the design was never implemented.

#4 was a streamside mitigation next to a residential home. The mitigation was not installed as designed or as appropriate to riparian area. As-builts, though required, were never submitted. Other areas of this rural property were denuded of ferns and shrubs transplanted to the mitigation area, which is >65% Himalayan blackberry and horsetail that were never maintained because the owner believed they were "natural".

#9 was performed by a public agency. Massive site failure in 1992 resulted in an agreement to install over 200 trees and shrubs. 1997 inspection showed this had not been done. Tree and shrub cover was <15% overall. Reed canary grass comprised >60% of emergent cover.

#10 failed over 90% of area and was not re-installed despite inspector's requirement for Contingency Mitigation Plan (this was counted as "Not Installed").

#13 was a bioswale with a PSS* buffer. The swale had >75% reed canary grass cover, <15% of the designed slough sedge and small-fruited bulrush. In the buffer, woody cover was <20%, and 34 of 119 shrubs, and 8 of 9 trees were found — the latter were all planted in a row against the fence, not clustered as the plans called for. Dumping was observed in the bioswale, mostly lawn clippings and yard waste.

#14 consisted of shrub plantings around a south-facing R/D pond. 1996 inspection revealed cover of <5% and survival of <1%. Soil is very stony and compacted, slopes are approximately 2:1, and site was designed for many shade- or water-dependent plants that failed in full sun on compacted till.

#16 was installed, and bond was reduced to maintenance level (30% of original). No monitoring report was received, as required, and apparently no maintenance was ever done. Alders that sprang up in the buffer were cut down. Shrub survival was <80%, and cover was <25%. Hydroseeding specified in design was bending planted shrubs to the ground.

#17 was installed to mitigate for stream buffer dumping, apparently without removing the fill and covering subsoil with 4" of topsoil, as specified, but only covering fill with topsoil. After complete failure, plants were re-installed, but failed again on gravel fill. Agency directed re-installation, which was not done. Counted as "Not Installed".

#18 was the only site >1 acre. At 3.26 acres, this site was composed of 11 separate wetland and stream mitigations, as well as an off-site stream enhancement. The R/D pond portion of this site was designed to be backfilled with 18" of soil, which was never done, and sedge, bulrush, and *Sparganium* plantings failed (replaced by volunteer *Potamogeton)*. Other areas imitated steep (2:1) slopes of the R/D pond, and were compacted to be stable at that angle. Site as a whole was dominated by Himalayan blackberry (>65%) or mowed, and survival was very poor. Site was generally designed for PSS* shrubberies, with some inappropriate trees, e.g., Sitka spruce in upland buffers. Swing sets and rose gardens had been installed in buffer.

#20 was a stream restoration with in-stream logs and buffer and upland enhancements. The upland plantings were never installed and one side of the stream buffer was never installed. The more easily accessible side was planted in full summer and many plants failed. Monitoring reports revealed that consultant believed Himalayan blackberry was a native plant that constituted shrub cover. Plants designed were shade-dependent, inappropriate for a west-facing compacted slope (3:1). No maintenance was done, but shrubs in PSS* design could not thrive in soil — some were smaller four years after installation than when they went in.

#22 was a streamside restoration for grading violation. Plantings on least accessible side of creek were in good condition, but newly cleared on near side of creek, where plantings had survival rate of 15%. Volunteer alders, etc., appeared to have been newly cut.

#23 was a very simple wetland enhancement: the design called for seven western redcedars and seven western hemlocks to be planted "in the wetland and buffer". This had not been done.

#24 was a stream buffer enhancement/restoration with created bioswale. The bioswale plantings failed initially; replanting to willow slips also failed. Buffer plantings failed due to inappropriate design, lack of maintenance, yard waste dumping, and neighbors who mowed buffer and installed swing sets, planter boxes, and non-native vegetation.

#26 was an enhanced stream buffer that was not maintained, and plantings failed because they were outcompeted by many invasive shrubs.

#28 was a stream buffer restoration for grading violation. Some plantings had been installed in a neat line along the existing streamside vegetation, but other shrubs had either never been installed, or had been mowed. Additional grading violations appeared to have been committed.

#29 was an enhanced buffer of a bioswale and three-cell R/D pond. The design called for installation of PSS* and emergents in the cell margins. Slopes were 2:1, compacted, and covered by excess quarry spall. Overall survival was <50%; overall cover was <15%. Some areas designed for emergents had <5% cover. Some dumping was found.

#30 was a stormwater system with bioswales and enhanced buffers. PSS* plantings had nearly 80% failure in full sun, on stony, compacted 2:1 slopes without irrigation. Emergents failed in bioswales probably because hydrology inputs were spiky, and appropriate shrubs could not be installed due to maintenance concerns.

#31 was a school R/D pond with bioswale and associated emergent wetland. The inundated areas (5% of site) had good willow and soft rush cover. The bulk of the site was south-facing 1:1 compacted slopes and survival was <5% of shade-tolerant and shade-dependent PSS* species.

#32 was an enhanced emergent wetland with enhanced scrub-shrub and upland buffer. The shrubs were PSS* species, and the upland a mixture of PSS* with water- and shade-dependent trees, e.g., western redcedar and western hemlock. The site had not been maintained, and grasses had bent shrubs to the ground. Very low survival rates, and <20% overall woody cover.

#33 was a commercial site with enhanced buffer. Some portions were never installed, while others were on newly created buffers (buffer averaging) that had compacted 2:1 slopes. Overall cover was <25%, and many planted individuals were very stressed. Note that no volunteers had arisen in most of buffer, though a dense stand of cottonwoods was observed on the undisturbed area beyond the buffer plantings.

#37 was a residence next to a perennial stream. The mitigation consisted of planting streamside buffer to red-osier dogwoods, cedars, willow slips, and nootka rose. The site was so covered in Himalayan blackberry and morning glory (>75% cover) that a full inspection could not be performed. No maintenance had ever been done, and a large pile of yard waste and soil had been dumped within 10' of the stream.

#38 was a wetland enlargement created by grading adjacent area down to wetland bottom level. It had very poor survival rates due to design that called for water-dependent plants where hydrology had been altered to create drier conditions, as well as: poor topsoil, full sun, competition from invasives, and lack of irrigation. Mitigation failed over 90%, but plantings were not replaced despite agency direction. Counted as "Not Installed".

Failures over less than 40% of area. These mitigation sites typically failed over 20% or more of area, i.e., one portion or more did not succeed.

#11 had one area that did not succeed — shade-tolerant plants were designed for a south-facing corner on fill that had not been excavated as called for. Himalayan blackberry and Scots broom dominate the area.

#21 was a wetland restoration: fill removal, bioswale creation, and buffer re-creation. Some of the fill was never removed, and plantings did not survive in that area — even a dense stand of volunteer cottonwoods hadn't moved in. Bioswale buffer plantings were mowed, and hydrology not appropriate to obligate emergents designed for in-swale area.

#34 was a school R/D pond with an adjacent emergent wetland and enhanced buffers of both. Though steep (3:1), buffers did not appear to have been unduly compacted, and alders were thriving, except on south-facing slope which was largely exposed gravel. Invasives had begun to block hydrology outlet, and were coming in on R/D buffer slopes.

#36 was a waterway relocation, stormwater management pond, and buffer enhancement. Most of this site was densely planted (twice as many as design called for) with good hydrology, but part of it was covered with dumping, including dumped concrete. Vine maple, paper birch, and roses survived but lacked vigor.

TABLE I: CAUSES OF WETLAND MITIGATION SITE FAILURE

KEY TO HEADINGS: "Type": BF=Buffer; BS=Bioswale; PEM, PFO, PSS=Cowardin wetland class, PSS*=bastardized design of scrub-shrub, sub-canopy, other shrubs; R/D=Retention/Detention Pond used as wetland mitigation, ST=Stream. "Design Flawed": Hydrology=Inputs not as represented in design, i.e., not enough water, not for long enough; Plants Wrong=Either shade-dependent plants in full sun or wetland plants in dry buffer; Steep Slopes=Slopes 3:1 or steeper. "Installation Flawed": Not to Design=Different spp. or different number of species or differently placed than as designed; Compacted Soil=subsoil exposed by excavation *OR* soil compacted by heavy machinery; No Organics=no compost or other soil amendment. "Maintenance Flawed": Mowed=mowed; Not Weeded=invasives not controlled; No Mulch/ Irrigation=plants not mulched, irrigation not provided.

SITE	MITIGATION TYPE	MITIGATION COMM'TIES	DESIGN FLAWED			INSTALLATION FLAWED			MAINTENANCE FLAWED			PROP. TYPE	RESULTS	OTHER
	C=Creation, R=Restoration E=Enhancement SS=Stormwater System	See Key for codes	Hydro-logy	Plants Wrong	Steep Slopes	Not to Design	Com-pacted Soil	No Or-ganics	Mowed	Not Weeded	No Mulch/ Irrigation			
2	C - BS with PSS* in BF	BS, PSS*,BF		X	X	X	X	X	X	X	X	Sub-Div	Buffer shrubs <5%.	Slopes 1.5:1; PHAR in BS
3	C - Relocated ST with PEM E - with PSS* & PFO in BF	PEM,PFO, PSS* BF	X X	X	X X		X X	X		X X	X X	Sub-Div	Woody veg. <25%	Bad wetland edge survey
4	R - ST buffer	PFO,BF				X				X		Res'dl	RUDI >65%.	Thought RUDI a native
9	C - Expansion of PEM with PSS* in BF	PEM,PSS*,BF	XX	X		X	X	X	X	X		Sub-Div	Woody veg. <15%	PHAR galore!
11	C - Expansion of PSS with PSS* in BF and BS	PEM,PSS,PSS*,BS, BF	XX	X	X	X	X	X		X	X	Sub-Div	Planted spp. 0% on fill	Fill not removed
13	C - BS with PSS* in BF	PEM,BS,PSS*,BF	X	X	X		X	X	X	X	X	Sub-Div	Survival 28%	Dumping, blocked inlet
14	C - R/D with PSS* in BF	R/D, PSS*,BF	X	X		X	X	X		X	X	Sub-Div	Woody veg. <5%	Faces full south...
16	E - PEM and BF with seral spp.	PEM,BF					X	X	X	X		Sub-Div	Woody veg. <25%	Grass strangling shrubs
18	C - PEM SS - R/D with PSS* in BF E - PEM & ST	All & PSS*	X	X X	X XX	 X	X X X	X X X	X X X	X X X	X X X	Sub-Div	Woody veg. <20%	NO Maintenance...
20	C - Relocated ST with PSS* BF	ST,PSS*,BF	X	X	X	X	X	X		X	X	Sub-Div	Woody veg. <20%	2/3 of mitig. not in
21	C - BS R - Remove fill in wetland (incomplete)	PEM,PSS,BS,BF	 X			 X	X X	X X			 X	Sub-Div	0% survival on fill	Fill not removed
22	E - Replace trees cut down	PFO, ST BF				X			X			Res'dl	15% survival	Mitig. cut down
24	E - BS in stream buffer	PFO,PEM,BF,BS	X	X		X	X	X	XX	X		Sub-Div	Woody veg. <25%	Mowed & swing sets in!
26	R - Success E - Buffer with PSS*	PEM,PSS,PFO PSS*								 X	 X	Res'dl	Buffer shrubs failed where not maintained.	Litany of invasives here
28	R - Buffer	ST-BF				X			XX	X		Sub-Div	Woody veg. <20%	Some in as decoration...

SITE	MITIGATION TYPE	MITIGATION COMM'TIES	DESIGN FLAWED			INSTALLATION FLAWED			MAINTENANCE FLAWED			PROP. TYPE	RESULTS	OTHER
	C=Creation, R=Restoration E=Enhancement SS=Stormwater System	See Key for codes	Hydro-logy	Plants Wrong	Steep Slopes	Not to Design	Com-pacted Soil	No Or-ganics	Mowed	Not Weeded	No Mulch/ Irrigation			
29	C - SS with PSS* in BF	PSS*,PEM,R/D,BF	X	X	X	X	X	X				Comm'l	Woody veg. <15%	Failure on quarry spall...
30	C - SS with PSS* in BF	PEM,PSS*,BF	X	X	X		X	X	X	X	X	Sub-Div	Woody veg. <15%	Buffer rock-hard
31	C - SS with PSS* in BF	R/D,BS,PSS*,BF	X	X	XX		X	X	X		X	Comm'l	Woody veg. <5%	Slopes 1:1 facing south
32	E - Buffer (this part failed)	PEM,PSS*,BF		X			X	X		X	X	Sub-Div		Grasses strangling shrubs
33	C - Buffers (regraded for BF averaging)	PSS*,BF	X	X	XX	X	X	X	X		X	Comm'l	Woody veg. <10%	Neglected since birth
34	C -SS with PSS* in BF	R/D,PEM,PSS*,BF	X	X	XX		X	X			X	Comm'l	Woody veg. <20%	Just on 1:1 gravel slopes
36	E - Buffer of SS & Stream	PSS,BF										Sub-Div	Woody veg. >50%	Dumped concrete 1 spot
37	E - Buffer	ST-BF								X	X	Res'dl	RUDI >70%	Can't tell if all in...
38	C - PEM	PEM, BF	X	X			X	X		X	X			