Final Report Submitted to the Ontario Cattlemen's Association

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Grazing Cattle and Riparian Ecosystems

E. Ann Clark, Ian Duncan, Peter Kevan, D. Peter Stonehouse, and Hugh Whiteley,
University of Guelph

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A. Executive Summary

The quality of water downstream of grazing beef cattle was not distinguishable from the quality of water entering pastured stretches of two watercourses in Ontario, except immediately after an access event. Neither chemical/microbial indices in flowing water nor indices of benthic invertebrate biodiversity could detect adverse impact in streams in Huron and Wellington counties. This does not mean that defecation and urination did not occur in pastured streams, but rather, that background levels of pollutants in water entering pastured streams were sufficiently high as to preclude detection of additional loading, if any, within the pasture. Indeed, levels of coliforms resident in streambottom sediments were so high that simply walking across a stream dragging a rake could duplicate the burst of elevated streamflow coliforms found immediately downstream of cattle crossings at both sites.

Risk of direct deposition of fresh feces by pastured beef cattle was assessed with dawn-to-dusk monitoring of beef cattle behavior in and near water on 8 pasture farms, 1 or more times a year over 3 years. In contrast to the behavior reported by others for drylotted cattle, 52 site-days of direct observation revealed that in-stream defecation and urination were infrequent in beef cattle grazing for nutrition. Voiding and lounging behavior of pastured beef cattle appear to be different from that reported by others for drylotted cattle grazing for recreation, or for range cattle in arid environments. In Ontario, cattle accessed flowing watercourses for drinking or for crossing, but seldom lounged in the water as is commonly observed in ponds and dugouts. Thus, direct observation of cattle behavior supported the chemical/microbial and benthic invertebrate studies suggesting that grazing beef cattle do not contribute meaningfully to direct pollutant loading in Ontario streams.

However, cattle can contribute indirectly to impairment of downstream water quality, and this may be where cattle producers can make their biggest contribution to improving surface water quality. Streambottom sediment plays a critical but hidden role in potential pasture effects on downstream water quality and herd health. Fecal coliforms and other microbes, some of which are pathogenic to cattle, may live for a year or more in stream sediments. Because coliforms travel, either as free floating individuals or on stream-borne suspended sediments, the coliforms resident in the streambottom sediments of any given stretch of pastured watercourse could have come from anywhere, whether from the pastured animals themselves or from upstream sources -

including pastured livestock, septic systems, drylot runoff, and land applied manure.

The primary source of sediment delivery to surface water systems is tillage of arable land, but pastured livestock can also be a factor if grazing or access behavior destabilize streambanks. Overgrazing near-edge vegetation weakens both the canopy and root system which protect and buffer streambanks against the natural erosive forces of storm and runoff events. When streambanks cave in, not only is fresh sediment delivered to the stream but the stream becomes wider and shallower, slowing flow and allowing sediment, and sediment-bound microbes, to accumulate within the pastured stretch.

Thus, in addition to direct deposition of fresh feces, pastured cattle can contribute to downstream pollution in two indirect ways: simply by crossing a watercourse, resuspending sediments which are then carried further downstream, and by destabilizing streambanks, facilitating sediment delivery to the streams. In the 8 monitored pastures, cattle almost always accessed water at a few preferred crossing points. Thus, reinforcing preferred crossings with inexpensive, locally available materials may be a cost-effective way of reducing sediment delivery and resuspension. Cross-fencing to support rotational grazing down a watercourse can control near-edge grazing, maintain streambank cover, narrow the channel, and maintain flow. These practical management practices are offered for consideration by producers seeking to reduce risk of impairing downstream water quality with grazing cattle.

B. Project Objectives

1. To document the current state of knowledge on interactions between grazing cattle and riparian ecosystems in the humid, temperate zone.

2. To identify, using GIS and existing databases, those regions of the province with greatest degree of overlap between grazing cattle and watercourses, and to characterize the distribution of watercourse types/attributes in the targeted areas.

3. To develop methodologies for assessing short- and long-term impacts of grazing livestock, including those able to distinguish faecal contamination from livestock vs. wildlife.

4. To relate diurnal, seasonal, and herd-to-herd variations in cattle behavior in and around watercourses to such variables as herd size and management, grazing management, specific pasture and watercourse features, prevalence of biotic stressors, such as face and heel flies, and microclimate.

5. To determine the effectiveness of managerial interventions, other than fencing, in modifying cattle behaviors expected to be harmful to the integrity of the riparian ecosystem**.**

6. To undertake cost:benefit studies into the on-farm, and some off-farm economic implications of various interventions intended to maintain or improve the integrity of riparian ecosystems accessed by grazing cattle.

C. Results and Conclusions of Project

Objective 1. Literature reviewed in the various documents prepared for this study revealed several key themes. Studies comprehensively reviewed by Clark (1996 and 1998) underscored the **site specificity of potential impacts** by uncontrolled grazing livestock on downstream water quality. Numerous factors influence potential impact, including prevailing climate, and hence, the relative attractiveness of the riparian zone to livestock; landform and soil type; biophysical characteristics of the watercourse; and pasture and herd management practices.

While provincial policy reflects the perception that grazing cattle are incompatible with a healthy riparian zone, a rigorous literature review suggested that this should be viewed as a testable hypothesis on a site by site basis, rather than accepted as a universal. Particularly in light of subsequent research, much of the more widely cited evidence of adverse livestock impacts does not appear to pertain well to Ontario in general and to pastured beef in particular. Much of the data collected through the provincial CURB (Clean Up Rural Beaches) program, for example, appears to have been collected on drylotted dairy cattle rather than grazing beef cattle. Other prominent studies were conducted on arid rangelands, where the riparian zone exerts a particularly magnetic effect on grazing cattle, or on ponds and dugouts rather than flowing water systems. Animal behavior towards and impact upon watercourses is fundamentally affected by the context of their habitat, as documented in the review by Duncan (1996).

A further problem identified by Clark (1996 and 1998) is the lack of evidence that grazing livestock are, in fact, a quantifiably important source of pollution in Ontario streams. It is likewise unclear that currently recommended practices, such as 100% exclusion, will in fact produce a measurable and cost-effective improvement in downstream water quality, particularly when applied to grazing as distinct from drylot situations..

It is concluded that extrapolating from existing Ontario databases on drylotted dairy cattle to encompass grazing beef cattle is not supported by the published literature, specifically because animal behavior and potential impact on downstream water quality are known to be context-dependent. Furthermore, downstream water quality responses to complete exclusion of grazing cattle have not be well documented. What is needed is a case-by-case analysis of preventative and/or remedial actions, focusing on those biophysical and/or managerial circumstances most likely to be problematic (see Objectives 2 and 4 below).

Thompson (1997) reviewed the potential risks and pathways of pathogen transmission from various agricultural sources, including pastured livestock, to humans. Pathogenic organisms are identified and described, as are the various factors affecting rate and pattern of die-off. Etiology, survival, and downstream transport of coliform bacteria are reviewed in the context of sampling methodology. Specific emphasis is placed on **sediment delivery and resuspension** by cattle access as a vehicle for downstream movement of transient coliforms on an annual cycle. As a result of the multiple sources of coliform contamination of Ontario watercourses, including tile drainage of surface applied manure, feedlot runoff, and leaking septic systems, it is difficult to attribute causality to the elevated downstream coliform concentrations immediately below cattle crossings (see also Whiteley, 1998).

Objective 2. To identify, using GIS and existing databases, those regions of the province with greatest degree of overlap between grazing cattle and watercourses, and to characterize the distribution of watercourse types/attributes in the targeted areas. On our behalf, MacDonald (1998) supervised a windshield survey of four regions in the province, involving a set of prepared questions assessing the potential for livestock impact on watercourses which were intersected by rural roads. Data from 472 roadside observation points were integrated into existing geographic databases using GIS technologies. His focus was not to measure actual impact, but rather to test the hypothesis that the *potential* for impact could be predicted from biophysical attributes such as landform, soil type, and predominant land use.

Of the sites judged to be "at some risk" (defined to be areas of pasture or hayland adjoining an unfenced watercourse), most were located on floodplain land or on land classified as "organic" on soil survey maps. It is suggested that the soil type(s) which is most typically used for pasture in a given region may be a useful index for targeted watercourse protection efforts. In Renfrew County, for example, 40% of the sites judged to be "at some risk" were found on Renfrew soil, a soil type that accounted for just 7% of the land area in the county. And of course, the other factor most predictive of the potential for livestock interaction with watercourses was the predominant land use. Livestock-dominant regions had 50% more sites judged to be "at some risk" than mixed crop-livestock regions.

The trends suggested in this preliminary study should be elaborated to allow a more rigorous test of the hypothesis, with the aim of identifying objectively those areas of the province most likely to be at risk of adverse livestock impact, and hence, targeting research and extension effort.

Objective 3. To develop methodologies for assessing short- and long-term impacts of grazing livestock, including those able to distinguish fecal contamination from livestock vs. wildlife.

Diagnostic Methods. As discussed in Whiteley (1998), fecal coliform and other microbes found in watercourses can originate from human and wildlife as well as agricultural sources. The latter can originate from both confined and pastured livestock. Thus, when bacteria are found in a watercourse, it is essential to correctly identify the predominant source(s) in order to take effective corrective action.

On our behalf, Dr. Patricia Seyfried and Lawrence Puente of the University of Toronto reviewed the literature and developed a novel "indicator bacteria" approach to distinguish likely sources of animal-origin bacteria. Two yellow-pigmented species of enterococci, *Enterococcus casseliflavus* and *E. mundtii,* were found to be present in many sources of fecal material, including human as well as domestic animals and wildlife. However, **sensitivity profiles for antibiotic resistance** were found to differ among sources, allowing successful identification of source 70% of the time. For example, isolates from wildlife sources were found to exhibit significantly higher resistance to vancomycin and arthromycin and significantly less resistance to cephalothin than domestic animals, with agricultural sources intermediate.

Further refinements in this promising and workable discriminatory technique have been

developed. If successful, this technique could prove most useful in identifying sources of fecal contamination found in watercourses and better targeting remedial measures.

Methodology for Studying Impact of Pastured Livestock. Separate methodological studies were conducted by Kevan (1996) and Kevan and Belaoussoff (1997) on benthic invertebrates and Whiteley (1998) on chemical and microbial indices to assess degree of livestock impact on watercourses. Both sets of researchers worked for two years monitoring impact on the same pastured section of the Jacklin/Hall municiapl drain in Huron County. In addition, Whiteley (1998) analyzed sampling studies conducted on the Cold Creek and Snake River watersheds in eastern Ontario (Northumberland and Renfrew counties, respectively) by Ed Reid and colleagues (OFAH) under the W3 program, as well as monitoring work at a second site at Carroll Creek in Wellington County in 1997.

Benthic invertebrate biodiversity is an integrative index of the history of pollution at a given site. The presence of pollution is inferred when species which are known to be insensitive to pollution predominate, while those known to be sensitive diminish, affecting both species diversity and richness. In addition, benthic invertebrates perform cleansing or polishing functions in polluted water, and are thus beneficial to overall water quality. To assess the impact of pastured cattle in Huron County, samples were collected in July and September of each year at each of 5 sites within the Jacklin/Hall drain, as well as 2 sites in the nearby Little Maitland River (Kevan (1996) and Kevan and Belaoussoff, 1997). Several indices were calculated from species presence and abundance data to assess both biodiversity per se, and the similarity in biodiversity among sites rated as impacted or not impacted.

The hypothesis that cattle activity adversely affected benthic biodiversity was not supported by the data in either year, in part because the entire watercourse, including upstream of the pasture itself, was already disturbed. Sites rated visually as cattle-impacted yielded biodiversity indices indistinguishable from those at cattle-unimpacted sites. It was thus not possible to discern additional impact, if any, within the pastured reaches of the Jacklin/Hall drain or Little Maitland River. This finding is supported by other parameters reported by Whiteley (1998)(below).

Physical, chemical, and microbial data, including suspended sediments, Total P, ammonia, *E. coli*, and fecal streptococci, were collected by Reid in eastern Ontario. In analysing this data, Whiteley (1998) concluded that background levels of contamination for all indices except ammonia - with or without cattle - tended to exceed provincial guidelines most of the time. When water entering pastures is already heavily contaminated by upstream sources of pollution, it is difficult to distinguish possible impacts of grazing livestock. Similar findings were reported by Thompson (1997) and Whiteley (1998) from Huron and Wellington county pastures. In both eastern and western regions, background (entering) levels of fecal coliforms commonly exceeded 1000 FC/100mL, or more than an order of magnitude greater than the provincial drinking water standard of 100 FC/100 mL. Against such a polluted background, it is difficult or impossible to detect additional in-pasture loadings of fecal coliforms if and when they occur. This does not mean that impact is not occurring - just that it cannot be detected.

Sedimentation and resuspension. Further complicating the determination of “new”

impact from grazing livestock is the role of sediment in storing and transporting viable coliforms in both time and space. Evidence cited in Thompson (1997) suggests that more than 95% of microbes introduced into a watercourse fall out of streamflow and into stream bottom sediments within 50 m of where they enter the stream. The resultant repository or bank of viable, stored microbes is thus available for resuspension and movement downstream following disturbance, whether due to cattle access or a spring flooding event. Further cited evidence suggests that the concentration of fecal coliforms per unit volume can be 100 to 1000 times greater in stream bottom sediment than in the flowing water itself.

Whiteley (1998) reported large-scale enrichment of streamflow bacteria at and immediately downstream of cattle access events (e.g. from a predisturbance level of 1200 to a post-disturbance level of 104,000 FC/100 mL at Carroll Creek in Wellington county, with similar trends in Huron County). It might be inferred that such a striking increase represents fresh pollutant loading by the cattle themselves. However, the same 10-100 fold increase in streamflow bacteria concentration could be caused artificially, just by having a person walk across the stream dragging a rake. He concludes that "it is plausible that the elevated concentrations during sampled (N.B.cattle origin) disturbances ...could be almost entirely from resuspended sediments".

The original source of the coliforms found in streambed sediments needs to be correctly identified, without necessarily assuming they came from the pastured stock themselves. Whiteley (1998) noted that the sampled municiapl drain in Huron county is in a watershed that supports 62 operating farms, of which 18 raise cattle. Immediately upstream of the pastured section of the municipal drain are three confinement operations, all of which spread liquid manure onto tiled land which empties into the same municipal drain.

Objective 4. To relate diurnal, seasonal, and herd-to-herd variations in cattle behavior in and around watercourses to such variables as herd size and management, grazing management, specific pasture and watercourse features, prevalence of biotic stressors, such as face and heel flies, and microclimate.

Behavior of grazing livestock with uncontrolled access to a watercourse was monitored using dawn-to-dusk observers on one or more days per year for up to three years at each of 8 beef pasture farms in the province (Table 1)[1].
The watercourses encompassed within this dataset provided a wide range of biophysical attributes, with size ranging from 1 m wide in at the Dufferin county site to 20 m wide at the Little Maitland River in Huron county. Among sites, footing varied from gravelly to soft, tree cover ranged from heavily wooded to entirely absent, and herd size ranged from 10 to 80 cow/calf pairs. Two of the eight producers practiced some degree of rotational grazing, with the rest grazing continuously. Data were collected for from 1-3 years at each site, covering biophysical attributes (species composition, nutritional quality, stream parameters,

[1] Despite detailed investigation (Maitland, 1996) and two years of fieldwork, passive infrared sensors were not found to perform reliably as a means of monitoring cattle activity. The only currently feasible methodology involved in situ visual observation.

grazing patterns) and animal behavior in and near the water. Chemical, microbial, and benthic invertebrate indices were monitored for two years at one site.

Table 1. Descriptions of beef pasture operations of cooperating producers

Site No.	County; Descriptor	Pasture Size, ha	Watercourse			Grazing Regime	Alternative Water	Treed
			Length, m	Width, m	Depth, cm			
1	Dufferin; Credit River Watershed	3.3	20	1	30	cont[2]	early season	no
2	Northumberland; Cold Creek	21	520	10	50	cont	yes	no
3	Northumberland Pipeline	16	19	1	30	cont	no	no
4	Lanark; Grant's Creek	21	261	8	30	rotn	no	some
5	Renfrew; Muskrat Lake	45	12 (access)	wide lake	100-300	cont	no	some
6	Renfrew; Snake River Tributary	20	337	1-3	20	cont	no	some
7	Huron; Jacklin and Hall Municipal Drains	5	427	1.5	10-20	rotn	no	some
8	Huron; Little Maitland River	10	330	20	40	both	no	no
9	Oxford; Horner Creek	45	1970	9	40	cont	no	yes

A total of 52 site-days of monitoring were recorded, as documented in Duncan et al. (1998). For each site-day, number of animals "in" the water (at least one foot touching) or "near" the water was counted every 15 minutes. Time spent drinking or crossing, as well as number of animals defecating or urinating in or near the water were recorded.

Time in the water ranged from 0 to 1400 minutes/day for cows, although all but 2 site-days were less than 600 minutes/day. Calf time in water ranged from 0 to 800 minutes/day, but all but 2 site-days were less than 350 minutes/day. Herd size ranged from 10 to 85 cows (plus calves), all

[2] Cont=continuous; rot=rotational

of which were grazing for virtually all of their nutrition.

On 73% of the 52 monitored site-days, probability of in-stream defecation was "slight" (e.g. less that 5%) for cows (Duncan et al., 1998). Less than 5% of calves defecated in the stream on 44 of 52 days or 85% of the time. Probability of in-stream urination was slight on 45 of 52 days (87% of the time) for cows and 49 of 52 days (96% of the time) for calves. Indeed, probability of cow defecation or urination was 0% on 65 and 77% of the measured days, respectively, with comparable figures for calves being 77 and 87%, respectively. Cattle commonly accessed, drank, or crossed watercourses without voiding.

Incidence of high frequency in-stream voiding (e.g. >10% of the herd) occurred infrequently and sporadically, with little apparent relation to measured biophysical attributes or management practices, with one possible exception. Two sites characterized by a relatively wide crossing and firm, rocky bottoms produced an unusual incidence of in-stream voiding. At the Little Maitland River site, which was measured just once in each of two years, cow defecation was high and very high in the two years, respectively (data not shown). Lending more substance to the trend, cow defecation frequency was high (11-31%) on 5 of 12 measured days at Grant's Creek in Lanark county, with calf defecation being high (10-30%) on 3 of 12 days (data not shown). Otherwise, cattle voiding behavior was inconsistent among days within the same site and year, suggesting that factors other than those expected could have motivated unusual behavior.

A comprehensive review and diagnostic manual prepared by Sinclair and Kevan (1996) concluded that biting flies were unlikely to account for much of cattle behavior in or near water in Ontario. Therefore, it would appear that other factors, such as climate, reproductive cycling, or other stressors may be operating on these infrequent occasions.

Contrary to the behavior which has been reported for drylotted dairy cattle at streams or rangeland beef cows at dugouts, grazing beef cattle spent very little time actually in streams in Ontario, and correspondingly, exhibited a much lesser rate of in-stream voiding than has been reported for cattle in other contexts. This novel finding has clear implications for the generalizability of recommended management practices over environments and types of livestock operation..

Herd size did not appear to influence voiding behavior, with similar patterns expressed by herds ranging from 10 to 85 cows. However, risk of in-stream voiding increased with cow time spent in the water at a rate of 0.025% for each additional herd minute spent in the water. It might be surmised that applying management intended to reduce time spent in the water would therefore reduce direct livestock impact. However, grazing beef cows and calves already spend only an average of 6 and 4 minutes in the water daily, and risk of in-stream voiding is already slight in most cases. A more fruitful direction might be to investigate the cause(s) of the occasional days when cattle do spend more time in the water and exhibit a higher frequency of in-stream voiding.

Objective 5. To determine the effectiveness of managerial interventions, other than

fencing, in modifying cattle behaviors expected to be harmful to the integrity of the riparian ecosystem.

Evidence of direct impacts by grazing beef cattle on downstream water quality could not be detected in separate analyses of benthic invertebrate biodiversity by Kevan and Belaoussoff (1997) and physical, chemical, and microbial indices by Whiteley (1998), as reported above. Lack of quantifiable impact is consistent with the findings of Duncan et al. (1998), showing that grazing beef cattle spend little time in the water and commonly exhibit a low risk of in-stream voiding.

Nonetheless, cattle may exert indirect, adverse impacts on watercourse integrity, and ultimately, on downstream water quality. Such differences may relate to grazing proximity and trailing behavior along the watercourse, which serve to weaken ground cover and destablize the streambank. Another concern is the physical placement of feces adjacent to the watercourse, where fecal material, coliforms, and P may be vulnerable to runoff during spring flooding. A third concern would be the timeliness of cattle access during the grazing season. The species and soil of the riparian zone are most vulnerable to livestock damage when the ground is moist, as in the spring.

Therefore, while evidence generated by others in this project does not support a significant direct effect of grazing beef cattle on downstream water quality, it was nonetheless important to understand factors motivating their behavior near water, to provide guidance to producers seeking to reduce potential indirect impacts.

Preferred Crossings It was hypothesized that preferred crossings may be narrower, shallower, more stable underfoot, and/or easier to access than unpreferred points. Measurements made at crossings, and at points 50 m above and below crossings suggested that crossing points were not consistently narrower or shallower (Clark et al., 1998). Crossings were, however, accessed through gentler slopes, and stability underfoot was as high or higher at crossing points as at other places in the stream. The preference of cattle for gentler access slopes and for solid footing underneath would support the use of reinforced, low level crossings to facilitate access and reduce risk of sediment delivery and resuspension (see Whiteley, 1998).

Grazing Proximity and Landform Morphology. Farms differed significantly in mean grazing proximity (to the edge of the stream), reflecting site differences in landform morphology and adjoining vegetation as well as year differences in stocking rate and grazing management (Clark et al., 1998). At some properties, the stream was bordered by wet, marshy, soft soil occupied by wetland adapted vegetation which appeared to be unpalatable to stock. Whether due to uncertain footing or unpalatable vegetation, this combination of factors had the effect of distancing grazing impact by several meters from the streambank edge. At other properties, the land was gently sloping to flat, supporting upland vegetation right to the edge of the watercourse and encouraging grazing to within 5-20 cm of the edge. These properties are most at risk of streambank destabilization. Intermediate grazing proximities were measured at floodplain properties with a

meandering watercourse due to either a low stocking rate and/or patches of unpalatable herbs (e.g. lady's thumb; stinging nettle) growing along the edge of the watercourse in former oxbows or places of sediment accretion.

The degree to which near-edge grazing affects streambank stability would be expected to vary among these three types of properties, owing largely to uncontrollable factors relating to the landform itself. For some properties, natural conditions protect the watercourse but for those properties where near-edge grazing is a risk, controlled, rotational grazing would discourage overgrazing and promote a more robust streambank vegetation.

Cowpie Density. Density of cowpies adjacent to the watercourse was measured in near (0 to 2 m) and far (2-10 m) strata (Clark et al., 1998). Cowpie density (pies per 100 m of stream length) differed among farms in both the near and far strata in each measured year. Much of the variation among farms could be accounted for by stocking density (per unit watercourse length). However, high cowpie densities in the near stratum were also associated with managerial decisions, such as overwintering cows on the pasture. At another property, the watercourse was positioned along the edge of the pasture, separating the pasture from a barn which was regularly accessed by the cattle for salt and mineral. As a result, cattle were obliged to cross the watercourse at the same place every day, which served to concentrate manure in proximity to the watercourse. Clearly, management decisions such as placement of salt, mineral, and alternate water can impact cattle movements and the potential for watercourse pollution.

Disproportionately more cowpies were found in the near than in the far stratum on all farms, suggesting that the watercourse may have an attractive influence, much like that of a fenceline. Factors associated with highest near-stream manure density were trees, which encouraged camping behavior, and a long, thin pasture profile bissected longitudinally by the watercourse which favored trailing.

Support for the trailing hypothesis comes from patterns in soil resistance with distance from the watercourse. Soil resistance was monitored with a penetrometer, in 10, 5 m wide strata leading out perpendicularly from the watercourse (Clark et al., 1998). Three types of patterns were seen among farms, with the pattern seen being generally consistent among years within a given farm. Soil resistance a) was uniform throughout, b) increased with distance from the watercourse, or c) decreased with distance from the watercourse. The only property to exhibit the latter profile, where soil resistance was greatest at the watercourse and declined with distance, was at Horner Creek in Oxford county. This site was a long, rectangular heavily treed floodplain pasture with a widely meandering watercourse longitudinally arrayed down the middle. High near-stream soil resistance came from trails which were well established along some sections of the streambank.

Where the physical shape of the pasture and stream placement promote trailing behavior, cross-fencing to support rotational grazing down the watercourse would likely reducing trailing and help to stabilize streambanks. The beneficial role of trees in maintaining the integrity of the riparian zone may be offset in a pasture setting by the tendency of trees to attract livestock to

camp and defecate in proximity to the watercourse.

That said, however, it should be noted that bacterial die-off in pasture cattle manure is rapid, with fecal coliforms declining from 7,800 colony forming units $(CFU)^{-gDW}$ in fresh cow manure to 780 CFU^{-gDW} later in the same summer (Clark, 1997). Using mean N content figures for all recorded droppings (old and fresh), total N in cattle manure within 10 m of the watercourse on both sides (e.g. a 20 m wide strip of land) would have ranged from **2 to 9 kg N along the total watercourse length[3], equivalent to 2.3 to 7.8 kg N/ha m among farms.** These figures will underestimate actual N voided by a) the amount of N lost prior to sampling - whether by leaching or gaseous emissions and b) the amount of N in urine. Nonetheless, they help to put into context the degree of risk posed by cowpie deposition in proximity to watercourses.

Seasonality of Riparian Usage. Even when grazing was uncontrolled, livestock tended to defer grazing of riparian zones until after upland vegetation was diminished. Although half to two-thirds of the species present in the pastures were found exclusively in either upland or riparian zones, species common to both zones accounted for most of the available herbage at most sites (see below) (Clark et al., 1998). Thus, while unpalatable riparian species may have discouraged grazing at some sites, it seems likely that unstable footing or other undefined factors may have played a part at others. Sward height and soil resistance were usually negatively related, with tallest herbage on the softest ground (Clark et al., 1998).

Temporal trends in both grazing proximity and soil resistance lend some support for the observation that usage of the riparian zone by grazing cattle was limited in the early season and increased progressively with time (Clark et al., 1998). Trends were not conclusive, however, and the feasibility of using availability of upland grazing to minimize encroachment of livestock into sensitive riparian zones until later in the season should be examined.

Species Composition. Species biodiversity (# of species) and richness (% of contact points) were assessed in each of 2 years at 5 farms and 1 year at 3 farms (Clark et al., 1998). Number of plant species varied from 18 to 56 among the eight sites, with greatest overall biodiversity found in pastures with a large number of upland species.

Although each farm tended to be relatively unique in species composition, some generalizations may be made. Prominent grass or grass-like genera typically found only in the riparian zone included *Equisetum* (horsetails), *Carex* (sedges), *Sagittaria* (arrowhead), *Iris* (iris), *Phragmites* (common reedgrass), *Phalaris* (reed canarygrass), and *Juncus* (rush). Broadleaf genera similarly adapted to the riparian zone included *Lythium* (purple loosestrife), *Polygonum* (lady's thumb),

[3] To illustrate, at one farm, 7.5 g N/cowpie x 14 cowpies/100 m of watercourse = **104 g per 100 m of watercourse** (one side only), while that in the far zone (2-8 m) would have amounted to **7.5 g x 17 cowpies = 126.7 g, or a total in the 0-10 m zone of 230.7 g/100 m or 2.3 g/m.** Considering the total length (1969 m) and both sides, manure N within 10 m of this watercourse would have averaged a total of about 9 kg N (2.3g/m x 1969m x 2). On a land area basis, this would be equivalent to 2.3 kg N/ha.

Veronica (marsh speedwell), and *Verbena* (vervain). Genera consistently adapted to upland sites tended to include *Echium* (blueweed), *Phleum* (timothy), and *Medicago* (alfalfa). A large number of native and introduced genera were found in both zones, including *Agropyron* (quackgrass), most of the common introduced coarse grasses, *Muhlenbergia* (wirestem muhly), *Taraxacum* (dandelion), *Ranunculus* (various buttercups) and the *Trifolium* species (clovers).

Some genera were prominent at only one or two farms, as *Lycopsis, Hydrocotyle, Digitaria, Echinochloa, Arctium, and Lycopus* which are found only at Horner Creek. Thus, while some generalizations were apparent in species adaptation, each farm appeared to have a relatively distinctive array of species and species importance rankings. Differences among farms in both biodiversity and in species richness support the need for a site-specific approach to watercourse protection.

Objective 6. To undertake cost:benefit studies into the on-farm, and some off-farm economic implications of various interventions intended to maintain or improve the integrity of riparian ecosystems accessed by grazing cattle.

A survey by Sholubi and Stonehouse (1996) reported that $1.1 million in public funds had been received by Ontario beef producers in the last 12 years to protect flowing water systems (exclusive of wetlands, ponds, and lakes). Over this interval, approximately 1% of all beef producers participated in one or more of the various provincial or federal incentive programs, with 51, 18, and 31% of the funds spent on exclusionary fencing, reinforced crossings, and alternative watering systems, respectively. Grants, which were roughly 75% of total project cost, averaged $3,760 to individual producers.

This survey, which was based on polling the funding sources themselves, demonstrated several key points. Although varying somewhat with the type of installation, the total cost of a watercourse protection initiative in Ontario was on the order of $5000. The amount of public funds available to support watercourse protection (excluding wetlands) was sufficient for participation by only 1% of the beef producing community. Thus, for the other 99% of all beef producers to spend $5000 of their own money for watercourse protection would require a clear indication of benefit.to the beef operation itself. This benefit has not been demonstrated. The primary beneficiary of watercourse protection appears to be downstream users of the water, whether for recreation or domestic use.

Dobson and Stonehouse (1998) conducted a second survey at the producer level, under the auspices of the Ontario Cattleman's Association. Of 40 respondants to a short questionnaire, over 50% had installed exclusionary fencing while another 40% indicated either partial or limited exclusionary fencing. Over 42% had installed alternative water to discourage drinking from natural watercourses, while just 9% had reinforced river crossings. This pattern of choice, focusing heavily on exclusionary fencing, may reflect the emphasis of the CURB program in particular, and the MNR in general, on complete exclusion as a prerequisite for access to provincial funding, However, of those producers who provided cost estimates, a majority were

self-funded, without a government contribution, which would suggest producer agreement with the importance of exclusionary fencing. The proportion of respondants referring to watercourses in grazed pasture vs. drylots is unknown.

The primary benefit perceived by producers for most interventions was in reduced streambank erosion. A much more varied range of perceptions was expressed on the merit of the various interventions in reducing downstream pollution, with highest value given to exclusionary fencing..

Nonetheless, evidence from Duncan et al. (1998), Kevan and Belaoussoff (1997), Thompson (1997), and Whiteley (1998) in the present study would suggest that complete exclusion may well be unnecessary to protect downstream water quality in pastured (not drylotted) livestock. Conversely, their work would suggest that reinforced crossings - a choice adopted by just 9% of the producers surveyed - may well be the most critical and probably most cost effective (although this was not tested) of the options available to producers to protect downstream water quality.

D. Significance to Ontario Agriculture and Food Industries

Beef producers, and agriculturalists in general, are willing to do their part in protecting and conserving societal resources, including surface water systems. However, they need cost-effective vehicles to comply with societal expectations. They also need to be sure that the solutions they are being asked to adopt will, in fact, meaningfully address the actual sources of the problem(s). Uncontrolled stream access by pastured beef cattle was assumed under the CURB program to be a source of downstream water pollution. Under the CURB program, the single, universal solution to this problem started with 100% exclusionary fencing, a solution which was untenable or uneconomic for many beef producers.

The present study considered the delivery of coliforms, P, and other pollutants by pastured beef cattle to watercourses to be an hypothesis testable on a site-specific basis rather than a universal assumption. Under commercial conditions at farms located across the province, findings did not support the hypothesis that pastured beef cattle are a significant source of water qualitiy impairment at most sites. However, cattle access to a watercourse can and does deliver and resuspend bottom sediments and promote downstream movement of resident microbes, P, and other sediment-bound pollutants from whatever source. It is proposed that reinforcement of preferred access points may achieve much the same benefit as exclusionary fencing, at a fraction of the cost. However, a possible linkage of increased in-stream defecation with more stable footing should be further examined. Another approach to reducing access - alternative water - appears to have potential as a deterrent only if supplied in-paddock, to support drinking by one or two animals at a time throughout the day, or on a sufficient scale to allow the whole herd to drink within a short time.

Other indirect impacts, as through near-edge grazing and trailing, can impair water quality by

destabilizing streambanks, promoting caving in and sediment delivery. Likewise, a concentration of cowpies near the watercourse can be encouraged by both natural factors, as a treed riparian zone, and managerial factors, such as uncontrolled grazing. The riparian zone is also most vulnerable to damage by livestock encroachment when soils are moist, in early spring. It is proposed that controlled rotational grazing along successive sections of a watercourse can be effective in reducing both near-stream overgrazing and destabilization and the disproportionate concentration of cowpies near watercourses. Deferred grazing of the riparian zone may also be encouraged by ensuring sufficient upland herbage to support stock in the early spring.

E. Technology Transfer

Clark, E. Ann. 1996 Spoke with the board of the Cold Creek W3 program, to discuss their demonstration plans and directions.

Clark, E. Ann. 1996. Update on riparian research at Guelph. Presented to Bay of Quinte beef producers. Coddrington, ON.

Clark, E. Ann. 1997. Cattle and creeks - can they coexist? Presented to a workshop organized by the UVM Center for Sustainable Agriculture, Burlington, VT.

Clark, E. Ann. 1998 Cattle and creeks: can they coexist? Presented to the Great Lakes Grazing Conference, Akron, Ohio - February 1998 (also excerpted and summarized in Brown, C. 1998. Watercourse reprieve? Ontario Beef Farmer 34-38)

F. Publications

a) Peer Reviewed journal publications
Clark, E. Ann. 1998. Landscape variables affecting livestock impacts on water quality. Can. J. Plant Science 78:181-190.

b) Books and Reports

Clark, E. Ann. 1996. *Alternative Livestock Watering Systems*. Final Report for Agriculture Canada/Canadian Wildlife Service. Plant Agriculture, University of Guelph. 78 pp.

Clark, E. Ann; Duncan, I.J.H.; Maitland, Karen.. 1998. E*nvironmental and Managerial Determinants of Livestock Behavior Near Watercourses in Ontario*. Final Report to the Great Lakes Protection Fund. Plant Agriculture. University of Guelph. 26 pp.

Dobson, S; Stonehouse, D. Peter.. 1998. *Economic Analysis of Riparian Systems Protection by Ontario Beef Producers*. Unpublished report. Agricultural Economics and Business, University of Guelph .8 pp.

Duncan, I.J.H. 1996. *INTERIM REPORT. Observations of cattle at four sites in Ontario during summer 1995.* Unpublished report. Animal and Poultry Science, University of Guelph. 7 pp

Duncan, I.J.H. 1997. *INTERIM REPORT. Observations of cattle at four sites in Ontario during summer 1996.* Unpublished report. Animal and Poultry Science. University of Guelph 7 pp.

Duncan, I.J.H; Clark, E. Ann; Maitland, Karen. 1998. *Livestock behavior in and near watercourses in Ontario: 3 year summary*. Unpublished report. Animal and Poultry Science and Plant Agriculture, University of Guelph. 9 pp.

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MacDonald, K.Bruce. 1998. Characterizing sites for potential livestock:watercourse interactions. Unpublished report. Ontario Land Resrouce Unit, Agriculture and Agri-Food Canada, Guelph. 9 pp.

Maitland, Karen. 1996. Remote monitoring possibilities for cattle in riaprian areas. Unpublished report. Plant Agriculture, University of Guelph. 8 pp.

Sholubi, O. And D. Peter Stonehouse. 1996. *Participation by Ontario Beef Producers in Publicly Funded Watercourse Protection Initiatives.* Unpublished report. Agricultural Economics and Business, University of Guelph. 9 pp.
Sinclair, B.J.; Kevan, P.G. 1996. *Guide to Flies Affecting Livestock in Canada: Identification and Behavior of Cattle on Pasture.* Unpublished report. Environmental Biology, University of Guelph. 24 pp.

Thompson, Tracy. 1997. *Research Report - 1996 and Literature Review* (unpublished). School of Engineering. University of Guelph. 35 pp.

Whiteley, H. 1996. *Water Quality Investigations Related to Cattle/stream Interactions.* Unpublished report. School of Engineering, University of Guelph. 27 pp.

Whiteley, H. 1998. *Effects of Cattle Access on Bacteria Concentrations in Streams.* Unpublished report. School of Engineering, University of Guelph. 13 pp.

c) Conference Proceedings

Bagshaw, C.S;, Duncan, I.J.H.; Matthews, L.R.. 1998. Manipulating cattle behaviour to protect stream environments. In: *Proceedings of the 32nd International Congress of the*

International Society for Applied Ethology, (Eds I. Veissier and A. Boissy), Clermont-Ferrand, France.

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Clark, E. Ann. 1999. Factors motivating cattle behavior near watercourses in Ontario. Proc. Northeastern Branch American Society of Agronomy and Soil Science Society of America. p.43.

Duncan, I.J.H., 1996. Motivational and behavioural factors affecting water course access and water intake. In: *Animal Science Research and Development: Meeting Future Challenges* (Ed. L.M. Rode). pp. 57-69.Agriculture and Agri-Food Canada, Lethbridge, Alberta.

d) Popular Press Articles

Clark, E. Ann. 1996. Do herbage quality and species composition motivate livestock behavior near watercourses? Ontario Beef Research Update 1995. Univ. of Guelph, Agriculture and Agri-Food Canada, and OMAFRA, OAC Publication No. 0196:103-110

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